
1.1: PROBLEM DEFINITION

Apply critical thinking to an engineering-relevant issue that is important to you. Create a written document that lists the issue, your reasoning, and your conclusion.

SOLUTION

Student answers will vary.

NOTE TO INSTRUCTOR:

See Appendix A of this Chapter 1 Solution Manual document for active learning in-class activities that may be used as a follow-on to this assignment.

1.2: PROBLEM DEFINITION

Do research on the internet, then create a written document in which you
(a) define what inductive reasoning means and give two concrete examples, and
(b) define what deductive reasoning means and give two concrete examples.
Use the CT process to justify your reasoning and your conclusions.

SOLUTION

Student answers will vary.

NOTES TO INSTRUCTOR:

1. See Appendix A of this Chapter 1 Solution Manual document for active learning in-class activities that may be used as a follow-on to this assignment.
2. One could modify this problem statement. For example, to meet an ABET criterion, such as "demonstration that students have a knowledge of contemporary issues," one could change "an engineering-relevant issue" to "a contemporary engineering-relevant issue".

1.3: PROBLEM DEFINITION

Pick an engineered system that really motivates you. From your favorite engineered system, draft your own definition of engineering. Then, see if your definition of engineering fits the definition of engineering in §1.1. How does this definition compare with yours? What is similar? What is different?

SOLUTION

Student answers will vary.

NOTE TO INSTRUCTOR:

See Appendix A of this Chapter 1 Solution Manual document for active learning in-class activities that may be used as a follow-on to this assignment.

1.4: PROBLEM DEFINITION

Select an engineered design (e.g., hydroelectric power as in a dam, an artificial heart) that involves fluid mechanics and is also highly motivating to you. Write a one-page essay that addresses the following questions: Why is this application motivating to you? How does the system you selected work? What role did engineers play in the design and development of this system?

SOLUTION

Student answers will vary.

NOTE TO INSTRUCTOR:

See Appendix A of this Chapter 1 Solution Manual document for active learning in-class activities that may be used as a follow-on to this assignment.

1.5: PROBLEM DEFINITION

Situation:

(T/F) A fluid is defined as a material that continuously deforms under the action of a normal stress.

Issue:

Is the following statement best characterized as true or as false?

A fluid is defined as a material that continuously deforms under the action of a normal stress.

REASONING:

1. By definition, a fluid is a material that deforms continuously under the action of a “shear stress.”
2. The statement states “normal stress.”
3. Thus, the given statement is false.
4. Another reason why the given statement is false is that it is easy to find examples in which the given statement is not true. For example, fluid particles in a lake experience normal stresses and there is no flow (i.e. deformation).

CONCLUSION: The best answer is false

NOTE TO INSTRUCTOR:

See Appendix A of this Chapter 1 Solution Manual document for active learning in-class activities that may be used as a follow-on to this assignment.

In particular, the **Clicker or "Vote" Classroom Problem** method would be appropriate.

1.6: PROBLEM DEFINITION

No solution provided; answers will vary. Possible answers could be determined by googling "material properties", which would yield answers such as thermal conductivity, electrical conductivity, tensile strength, etc. The next step would be to discuss how each new material property was different for solids, liquids, and gases.

1.7: PROBLEM DEFINITION

Situation:

Based on molecular mechanisms, explain why aluminum melts at 660°C whereas ice melts at 0°C .

SOLUTION

When a solid melts, sufficient energy must be added to overcome the strong intermolecular forces. The intermolecular forces within solid aluminum require more energy to be overcome (to cause melting), than do the intermolecular forces in ice.

1.8: PROBLEM DEFINITION

Situation:

A fluid particle

- a. is defined as one molecule
- b. is a small chunk of fluid
- c. is so small that the continuum assumption does not apply

SOLUTION

The correct answer is b.

1.9: PROBLEM DEFINITION

Situation:

The continuum assumption (select all that apply)

- a. applies in a vacuum such as in outer space
- b. assumes that fluids are infinitely divisible into smaller and smaller parts
- c. is an invalid assumption when the length scale of the problem or design is similar to the spacing of the molecules
- d. means that density can idealized as a continuous function of position
- e. only applies to gases

SOLUTION

The correct answers are b, c, and d.

1.10: PROBLEM DEFINITION

Note: Student answers will vary. The CT process format (Issue/Reasoning/Conclusion) should be used.

An example answer is provided here.

Issue:

A lift force on an airfoil is caused by air pressure on the bottom of the wing relative to the top of the wing. Therefore, lift force is a pressure force. Use the CT process (see §1.1) to answer whether lift acting on an airfoil is a surface force, or a body force.

Reasoning:

Pressure forces and lift forces have molecules of fluid touching the surface of the wing, and touching is the distinguishing feature of a surface force. Therefore, lift is a surface force, not a body force. A body force is one caused by a field, such as a magnetic, gravitational, or electrical field. *Although gravity influences the pressure distribution in the atmosphere where the plane is flying, the lift (surface) force acts only because the air is pressed against (touching) the airfoil surface.*

Conclusion:

A lift force is a surface force.

1.11: PROBLEM DEFINITION

Situation:

Fill in the blanks. Show your work, using conversion factors found in Table F.1 (EFM11e).

PLAN

Do these unit conversions between different mass units.

Show your work - e.g. canceling and carrying units, using conversion factors found in Table F.1 (EFM11e).

a) _____

SOLUTION

900 g is _____ slug

$$900 \text{ g} = \left(\frac{900 \text{ g}}{1} \right) \left(\frac{1 \text{ kg}}{1000 \text{ g}} \right) \left(\frac{1 \text{ slug}}{14.59 \text{ kg}} \right)$$

$$20 \text{ g} = 0.0617 \text{ slug}$$

b) _____

SOLUTION

27 lbm is _____ kg

$$27 \text{ lbm} = \left(\frac{27 \text{ lbm}}{1} \right) \left(\frac{1 \text{ kg}}{2.205 \text{ lbm}} \right)$$

$$27 \text{ lbm} = 12.2 \text{ kg}$$

c) _____

SOLUTION

100 kg is _____ slugs

$$100 \text{ kg} = \left(\frac{100 \text{ kg}}{1} \right) \left(\frac{1 \text{ slug}}{14.59 \text{ kg}} \right)$$

$$100 \text{ kg} = 6.85 \text{ slug}$$

d) _____

SOLUTION

14 lbm is _____ g

$$14 \text{ lbm} = \left(\frac{14 \text{ lbm}}{1} \right) \left(\frac{453.6 \text{ g}}{1 \text{ lbm}} \right)$$

$$14 \text{ lbm} = 6350 \text{ g}$$

e) _____

SOLUTION 5 slug is _____ lbm

$$5 \text{ slug} = \left(\frac{5 \text{ slug}}{1} \right) \left(\frac{32.17 \text{ lbm}}{1 \text{ slug}} \right)$$

$$\boxed{5 \text{ slug} = 160.8 \text{ lbm}}$$

1.12: PROBLEM DEFINITION

Situation:

What is the approximate mass in units of slugs for

- a. A 2-liter bottle of water?
- b. A typical adult male?
- c. A typical automobile?

a) _____

PLAN

Mass in slugs for: 2-L bottle of water

SOLUTION

$$\left(\frac{2\text{L}}{1}\right) \left(\frac{1000\text{ kg}}{\text{m}^3}\right) \left(\frac{1\text{ m}^3}{1000\text{L}}\right) \left(\frac{1\text{ slug}}{14.59\text{ kg}}\right) = \boxed{0.137\text{ slug}}$$

b) _____

PLAN

Answers will vary, but for 180-lb male:

SOLUTION

On earth 1 lbf weighs 1 lbm

To convert to slugs

$$\left(\frac{180\text{ lb}}{1}\right) \left(\frac{1\text{ slug}}{32.17\text{ lb}}\right) = \boxed{5.60\text{ slug}}$$

c) _____

PLAN

Answers will vary, but for 3000-lb automobile:

SOLUTION

On earth 1 lbf weighs 1 lbm

To convert to slugs

$$\left(\frac{3000\text{ lb}}{1}\right) \left(\frac{1\text{ slug}}{32.17\text{ lb}}\right) = \boxed{93.3\text{ slug}}$$

1.13: PROBLEM DEFINITION

Answer the following questions related to mass and weight. Show your work, and cancel and carry units.

PLAN

Use $F = ma$, and consider weight and mass units.

In particular, be aware of consistent units and their definitions, such as:

$$1.0 \text{ N} \equiv 1.0 \text{ kg} \times 1.0 \text{ m/s}^2 \quad \text{and} \quad 1.0 \text{ lbf} \equiv 1.0 \text{ slug} \times 1.0 \text{ ft/s}^2$$

a) _____

SOLUTION

What is the weight (in N) of a 100-kg body?

$$\begin{aligned} F &= m \times a \quad \text{on earth} \\ W &= (100 \text{ kg}) (9.81 \text{ m/s}^2) \end{aligned}$$

$$W = 981 \text{ N}$$

b) _____

SOLUTION

What is the mass (in lbm) of 20 lbf of water?

$$\begin{aligned} m &= F/a \\ m &= \{\text{force}\} \times \{1/\text{acceleration on earth}\} \times \{\text{identity}\} \\ m &= \left(\frac{20 \text{ lbf}}{1} \right) \left(\frac{\text{s}^2}{32.2 \text{ ft}} \right) \left(\frac{1 \text{ slug} \times 1 \text{ ft/s}^2}{1 \text{ lbf}} \right) \\ m &= 0.621 \text{ slug; next convert to lbm} \\ m &= \left(\frac{0.621 \text{ slug}}{1} \right) \left(\frac{32.2 \text{ lbm}}{1 \text{ slug}} \right) \end{aligned}$$

$$m = 20 \text{ lbm}$$

c) _____

SOLUTION

What is the mass (in slugs) of 20 lbf of water?

$$\begin{aligned} m &= F/a \\ m &= \{\text{force}\} \times \{1/\text{acceleration on earth}\} \times \{\text{identity}\} \\ m &= \left(\frac{20 \text{ lbf}}{1} \right) \left(\frac{\text{s}^2}{32.2 \text{ ft}} \right) \left(\frac{1 \text{ slug} \times 1 \text{ ft/s}^2}{1 \text{ lbf}} \right) \end{aligned}$$

$$m = 0.621 \text{ slug};$$

d) _____

SOLUTION

How many N are needed to accelerate 2 kg at 1 m/s²?

$$\begin{aligned} F &= m \times a \\ F &= (2 \text{ kg}) (1 \text{ m/s}^2) \end{aligned}$$

$$F = 2 \text{ N}$$

e) _____

SOLUTION

How many lbf are needed to accelerate 2 lbm at 1 ft/s²?

$$\begin{aligned} m &= 2 \text{ lbm} \quad \text{convert to slugs for consistent units} \\ 2 \text{ lbm} &= \left(\frac{2 \text{ lbm}}{1} \right) \left(\frac{1 \text{ slug}}{32.17 \text{ lbm}} \right) \\ 2 \text{ lbm} &= 0.06217 \text{ slug} \quad \text{Now, use } F = m \times a \text{ with the consistent units} \\ F &= m \times a \\ F &= 0.06217 \text{ slug} \times 1 \text{ m/s}^2 \end{aligned}$$

$$F = 0.0622 \text{ lbf}$$

f) _____

SOLUTION

How many lbf are needed to accelerate 2 slugs at 1 ft/s²?

Here, units are already consistent

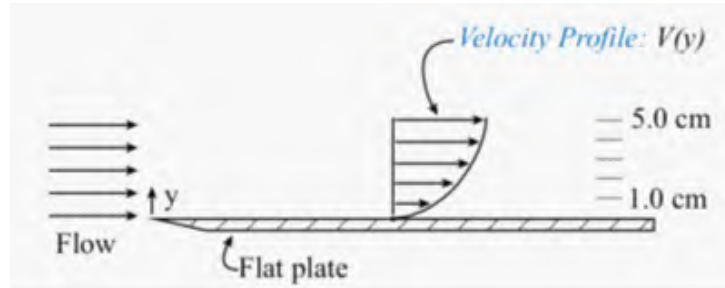
$$\begin{aligned} F &= m \times a \\ F &= 2 \text{ slug} \times 1 \text{ m/s}^2 \end{aligned}$$

$$F = 2 \text{ lbf}$$

1.14: PROBLEM DEFINITION

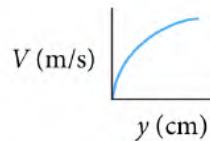
Situation: The sketch shows fluid flowing over a flat surface.

Find: Show how to find the value of the distance y where the derivative dV/dy is maximum.

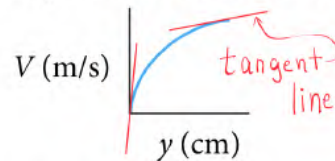


REASONING

1. If you redraw the curve so that the dependent variable (V) is on the vertical axis and the independent variable (y) is on the horizontal axis, the curve looks like this.



2. Now, if you draw a tangent line, the slope of the tangent line will equal the value of the derivative.



3. The y value where dV/dy is maximum is situated where the slope of the tangent line is steepest. This occurs at $y = 0$ cm.

CONCLUSION(S)

The derivative is maximum where $y = 0$ cm

1.15: PROBLEM DEFINITION

Situation: An engineer measured the speed of a flowing fluid as a function of the distance y from a wall; the data are shown in the table.

Find: Show how to calculate the maximum value of dV/dy for this data set. Express your answer in SI units.

y (mm)	V (m/s)
0.0	0.00
1.0	1.00
2.0	1.99
3.0	2.97
4.0	3.94

REASONING

Apply the definition of the derivative.

① The defⁿ of the derivative shows that.

$$\frac{dV}{dy} \equiv \lim_{\Delta y \rightarrow 0} \frac{\Delta V}{\Delta y} \approx \frac{\Delta V}{\Delta y}$$

② Thus, calc $\Delta V/\Delta y$ as shown below

Example

$2.97 - 1.99 = 0.98$

y (mm)	V (m/s)	ΔV (m/s)	Δy (m)	$\Delta V/\Delta y$ (s ⁻¹)
0.0	0.00	1.0	0.001	1000
1.0	1.00	0.99	0.001	990
2.0	1.99	0.98	0.001	980
3.0	2.97	0.97	0.001	970
4.0	3.94			

Example
 $\frac{.99}{0.001} = 990$

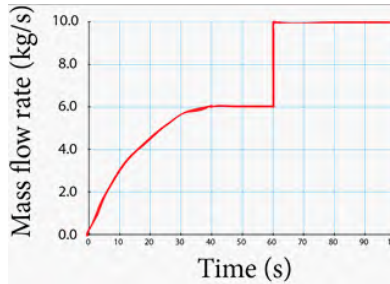
③ The maximum value of dV/dy is 1000 s⁻¹

CONCLUSION(S)

The maximum value of dV/dy is 1000 s⁻¹

1.16: PROBLEM DEFINITION

Situation: The plot shows data taken to measure the rate of water flowing into a tank as a function of time.



Find: Show how to calculate the total amount of water (in kg, accurate to 1 or 2 significant figures) that flowed into the tank during the 100s interval shown.

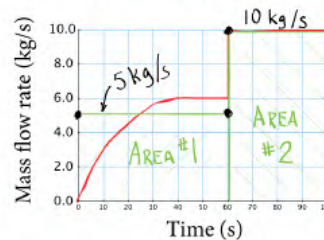
REASONING

1. This problem is an integration problem.

$$m = \int_{t=0}^{100s} \left(\frac{\text{mass}}{\text{time}} \right) dt$$

WHAT IS PLOTTED

2. The integration, shown below, gives the total mass.



$$\begin{aligned} m &\approx A_1 + A_2 \\ &= \left(\frac{5 \text{ kg}}{s} \right) \left(\frac{60s}{1.0} \right) + \left(\frac{10 \text{ kg}}{s} \right) \left(\frac{40s}{1.0} \right) \\ &= 700 \text{ kg} \end{aligned}$$

CONCLUSION(S)

$$m = 700 \text{ kg (accurate to about 2 SFs where SFs means significant figures)}$$

1.17: PROBLEM DEFINITION

Find:

How are density and specific weight related?

PLAN

Consider their definitions (conceptual and mathematical)

SOLUTION

Density is a [mass]/[unit volume], and specific weight is a [weight]/[unit volume]. Therefore, they are related by the equation $\gamma = \rho g$, and density differs from specific weight by the factor g , the acceleration of gravity.

1.18: PROBLEM DEFINITION

Situation:

Density is (select all that apply)

- a. weight/volume
- b. mass/volume
- c. volume/mass
- d. mass/weight

SOLUTION

Answer is (b) mass/volume.

1.19: PROBLEM DEFINITION

Situation:

Which of these are units of density? (Select all that apply.)

- a. kg/m^3
- b. mg/cm^3
- c. lbm/ft^3
- d. slug/ft^3

SOLUTION

Correct answers are a, b, c, and d. Each of these is a mass/volume.

1.20: PROBLEM DEFINITION

Situation:

If a gas has $\gamma = 14 \text{ N/m}^3$ what is its density?

State your answers in SI units and in traditional units.

SOLUTION

Density and specific seight are related according to

$$\gamma = \frac{\rho}{g}$$

$$\text{So } \rho = \frac{\gamma}{g}$$

$$\text{For } \gamma = 14 \frac{\text{N}}{\text{m}^3}$$

$$\text{In SI } \rho = \left(\frac{14 \text{ N}}{\text{m}^3} \right) \left(\frac{1 \text{ s}^2}{9.81 \text{ m}} \right)$$

$$\rho = \boxed{1.43 \frac{\text{kg}}{\text{m}^3}}$$

Converting to traditional units

$$\rho = \left(\frac{1.427 \text{ kg}}{\text{m}^3} \right) \left(\frac{1 \text{ m}^3}{(3.281^3) \text{ ft}^3} \right) \left(\frac{1 \text{ slug}}{14.59 \text{ kg}} \right)$$

$$\rho = \boxed{2.78 \times 10^{-3} \frac{\text{slug}}{\text{ft}^3}}$$

1.21: PROBLEM DEFINITION

Situation:

Calculate the number of molecules in:

- a) One cubic cm of water at room conditions
- b) One cubic cm of air at room conditions

a) _____

PLAN

1. The density of water at room conditions is known (Table A.5, EFM11e), and the volume is given, so:

$$m = \rho V$$

2. From the Internet, water has a molar mass of 18 g/mol, use this to determine the number of moles in this sample.
3. Avogadro's number says that there are 6×10^{23} molecules/mol

SOLUTION

- 1.

$$m = \rho_{\text{water}} V$$

Assume conditions are atmospheric with $T = 20^\circ\text{C}$ and $\rho = 998 \frac{\text{kg}}{\text{m}^3}$

$$\begin{aligned} m_{\text{water}} &= \left(\frac{998 \text{ kg}}{\text{m}^3} \right) \left(\frac{1 \text{ m}^3}{100^3 \text{ cm}^3} \right) (1 \text{ cm}^3) \\ m_{\text{water}} &= 0.001 \text{ kg} \end{aligned}$$

2. To determine the number of moles:

$$\begin{aligned} \text{number of moles} &= (0.0010 \text{ kg}) \left(\frac{1 \text{ mol}}{18 \text{ g}} \right) \left(\frac{1000 \text{ g}}{1 \text{ kg}} \right) \\ \text{number of moles} &= 0.055 \text{ mol} \end{aligned}$$

3. Using Avogadro's number

$$\begin{aligned} \text{number of molecules} &= (0.055 \text{ mol}) \left(\frac{6 \times 10^{23} \text{ molecules}}{\text{mol}} \right) \\ &= \boxed{3.3 \times 10^{22} \text{ molecules}} \end{aligned}$$

b) _____

PLAN

1. The density of air at room conditions is known (Table A.3, EFM11e), and the volume is given, so:

$$m = \rho V$$

2. From the Internet, dry air has a molar mass of 28.97 g/mol, use this to determine the number of moles in this sample.
3. Avogadro's number says that there are 6×10^{23} molecules/mol

SOLUTION

- 1.

$$m = \rho_{\text{air}} V$$

Assume conditions are atmospheric with $T = 20^\circ\text{C}$ and $\rho = 1.20 \frac{\text{kg}}{\text{m}^3}$

$$\begin{aligned} m_{\text{air}} &= \left(\frac{1.20 \text{ kg}}{\text{m}^3} \right) \left(\frac{1 \text{ m}^3}{100^3 \text{ cm}^3} \right) (1 \text{ cm}^3) \\ m_{\text{air}} &= 1.2 \times 10^{-6} \text{ kg} \end{aligned}$$

2. To determine the number of moles:

$$\begin{aligned} \text{number of moles} &= (1.2 \times 10^{-6} \text{ kg}) \left(\frac{1 \text{ mol}}{28.97 \text{ g}} \right) \left(\frac{1000 \text{ g}}{1 \text{ kg}} \right) \\ \text{number of moles} &= \boxed{4.14 \times 10^{-5} \text{ mol}} \end{aligned}$$

3. Using Avogadro's number

$$\begin{aligned} &(4.14 \times 10^{-5} \text{ mol}) \left(\frac{6 \times 10^{23} \text{ molecules}}{\text{mol}} \right) \\ \text{number of molecules} &= 2.5 \times 10^{19} \text{ molecules} \end{aligned}$$

REVIEW

There are more moles in one cm^3 of water than one cm^3 of dry air. This makes sense, because the molecules in a liquid are held together by weak inter-molecular bonding, and in gases they are not; see Table 1.1 in Section 1.2 (EFM11e).

1.22: PROBLEM DEFINITION

Situation:

Start with the mole form of the Ideal Gas Law, and show the steps to prove that the mass form is correct.

SOLUTION

The molar form is:

$$pV = nR_u T$$

Where n = number of moles of gas, and the Universal Gas Constant = $R_u = 8.314 \text{ J/mol} \cdot \text{K}$.

Specific gas constants are given by

$$\begin{aligned} R_{\text{specific}} &= R = \frac{R_u}{\text{molar mass of a gas}} \\ &= \left(\frac{8.314 \text{ J}}{\text{mol} \cdot \text{K}} \right) \left(\frac{\text{X moles}}{\text{g}} \right) \\ &= 8.314 \text{ X } \frac{\text{J}}{\text{g} \cdot \text{K}} \end{aligned}$$

Indeed, we see that the units for gas constants, R , in table A.2 (EFM11e), are

$$\boxed{\frac{\text{J}}{\text{g} \cdot \text{K}}}$$

So

$$pV = (R_{\text{specific}})(m)(T) \quad \text{and} \quad \rho = \frac{m}{V}$$

$$\boxed{p = \rho RT}$$

Thus the mass form is correct.

1.23: PROBLEM DEFINITION

Situation:

Start with the universal gas constant and show that $R_{N_2} = 297 \frac{\text{J}}{\text{kg} \cdot \text{K}}$.

SOLUTION

Start with universal gas constant:

$$R_u = \frac{8.314 \text{ J}}{\text{mol} \cdot \text{K}}$$

The molar mass of nitrogen, N_2 , is 28.02 g/mol.

$$\begin{aligned} R_{N_2} &= \frac{R_u}{\text{molar mass}} = \left(\frac{8.314 \text{ J}}{\text{mol} \cdot \text{K}} \right) \left(\frac{1 \text{ mol}}{28.02 \text{ g}} \right) \left(\frac{1000 \text{ g}}{1 \text{ kg}} \right) \\ &= \boxed{297 \frac{\text{J}}{\text{kg} \cdot \text{K}}} \end{aligned}$$

1.24: PROBLEM DEFINITION

Situation:

Spherical tank of CO₂, does $p_2 = 3p_1$?

Case 1:

$$p = 12 \text{ atm}$$

$$T = 30^\circ\text{C}$$

Volume is constant inside the tank

Case 2:

$$p = ?$$

$$T = 90^\circ\text{C}$$

Volume for case 2 is equivalent to that in case 1

PLAN

1. Volume inside the tank is constant, as is the mass.

Mass is related to volume by density.

2. Use the Ideal Gas Law to find P_2

SOLUTION

1. Mass in terms of density

$$m = \rho V$$

For both case 1 and 2, $\rho_1 = \frac{m}{V} = \rho_2$, because mass is contained by the tank.

2. Ideal Gas Law for constant volume

$$\begin{aligned}\rho &= \frac{p}{RT} \\ \rho_{1,2} &= \frac{p_1}{RT_1} = \frac{p_2}{RT_2} \\ \frac{p_1}{T_1} &= \frac{p_2}{T_2}\end{aligned}$$

The Ideal Gas Law applies ONLY if the temperature is absolute, which for this system means Kelvin. In the problem statement, the temperatures were given in Celsius. We need to convert the given temperatures to Kelvin in order to relate them to the pressures. We see therefore that the ratio of temperatures in K is not 1:3. Rather, $30^\circ\text{C} = 303.15 \text{ K}$, and $90^\circ\text{C} = 363.15 \text{ K}$.

Therefore, $\frac{T_2}{T_1} = \frac{363.15 \text{ K}}{303.15 \text{ K}} = \frac{p_2}{p_1} = 1.2$

$\Rightarrow$ No, p_2 does not equal $3p_1$. Instead, $p_2 = 1.2 p_1$

REVIEW

When working with the IGL, you must always use units for absolute temperature, which means convert T to Rankine (traditional) or Kelvin (SI).

1.25: PROBLEM DEFINITION**Situation:**

An engineer needs to know the local density for an experiment with a glider.

$z = 2500$ ft.

Local temperature $= 74.3^\circ\text{F} = 296.7$ K.

Local pressure $= 27.3$ in.-Hg $= 92.45$ kPa.

Find:

Calculate density of air using local conditions.

Compare calculated density with the value from Table A.2, and make a recommendation.

Properties:

From Table A.2 (EFM11e), $R_{\text{air}} = 287 \frac{\text{J}}{\text{kg} \cdot \text{K}} = 287 \frac{\text{N} \cdot \text{m}}{\text{kg} \cdot \text{K}}$, $\rho = 1.22$ kg/m³.

PLAN

Calculate density by applying the ideal gas law for local conditions.

SOLUTION

Ideal gas law

$$\begin{aligned}\rho &= \frac{p}{RT} \\ &= \frac{92,450 \text{ N/m}^2}{\left(287 \frac{\text{N} \cdot \text{m}}{\text{kg} \cdot \text{K}}\right) (296.7 \text{ K})} \\ &= 1.086 \text{ kg/m}^3\end{aligned}$$

$$\rho = 1.09 \text{ kg/m}^3 \text{ (local conditions)}$$

Table value. From Table A.2

$$\rho = 1.22 \text{ kg/m}^3 \text{ (table value)}$$

The density difference (local conditions versus table value) is about 12%. Most of this difference is due to the effect of elevation on atmospheric pressure.

Recommendation—use the local value of density because the effects of elevation are significant.

REVIEW

Note: Use absolute pressure when working with the ideal gas law.

1.26: PROBLEM DEFINITION

Situation:

Carbon dioxide.

Find:

Density and specific weight of CO₂.

Properties:

From Table A.2 (EFM11e), $R_{\text{CO}_2} = 189 \text{ J/kg}\cdot\text{K}$.

$p = 114 \text{ kPa}$, $T = 90^\circ\text{C}$.

PLAN

1. First, apply the ideal gas law to find density.
2. Then, calculate specific weight using $\gamma = \rho g$.

SOLUTION

1. Ideal gas law

$$\begin{aligned}\rho_{\text{CO}_2} &= \frac{P}{RT} \\ &= \frac{114,000 \text{ kPa}}{(189 \text{ J/kg}\cdot\text{K})(90 + 273) \text{ K}} \\ \boxed{\rho_{\text{CO}_2} = 1.66 \text{ kg/m}^3}\end{aligned}$$

2. Specific weight

$$\gamma = \rho g$$

Thus

$$\begin{aligned}\gamma_{\text{CO}_2} &= \rho_{\text{CO}_2} \times g \\ &= 1.66 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2 \\ \boxed{\gamma_{\text{CO}_2} = 16.3 \text{ N/m}^3}\end{aligned}$$

REVIEW

Always use absolute pressure when working with the ideal gas law.

1.27: PROBLEM DEFINITION

Situation:

Methane gas.

Find:

Density (kg/m^3).

Properties:

From Table A.2 (EFM11e), $R_{\text{Methane}} = 518 \frac{\text{J}}{\text{kg} \cdot \text{K}}$
 $p = 200 \text{ kPa}$, $T = 80^\circ \text{C}$.

PLAN

1. Apply the ideal gas law to find density.

SOLUTION

1. Ideal gas law

$$\begin{aligned}\rho_{\text{Methane}} &= \frac{p}{RT} \\ &= \frac{200,000 \frac{\text{N}}{\text{m}^2}}{518 \frac{\text{J}}{\text{kg} \cdot \text{K}} (80 + 273 \text{ K})} \\ \rho_{\text{Methane}} &= 1.09 \text{ kg}/\text{m}^3\end{aligned}$$

REVIEW

Always use absolute pressure when working with the ideal gas law.