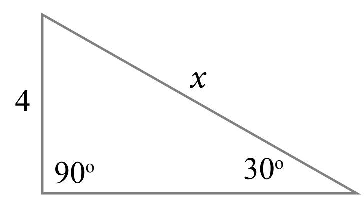
Problem 1.1

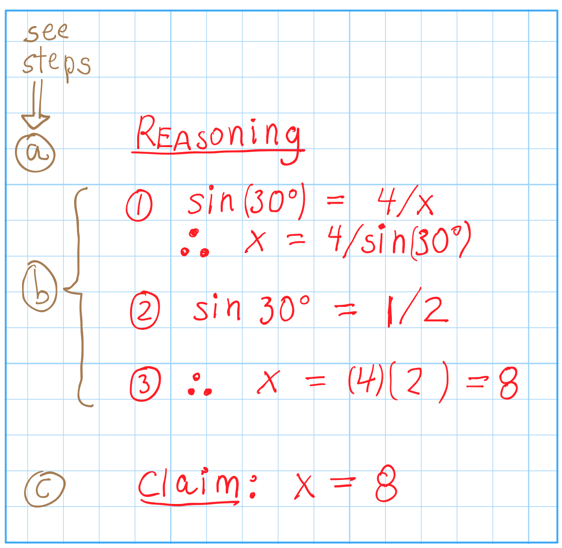
For the given problem, present a solution that demonstrates the standard structure of critical thinking.

Problem Statement
Calculate x for this triangle.



Feedback

One possible response follow:



The steps are

a. Label the reasoning
b. List facts in a logical order
c. State the claim

1.2: 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.

Problem 1.3

(T/F) The constant $g = 9.81\,\mathrm{m/s^2}$ can also be written as $g = 9.81\,\mathrm{N/kg}$.

Feedback

True, because a newton/kilogram is equivalent to a meter/second^2.

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

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

Problem 1.4

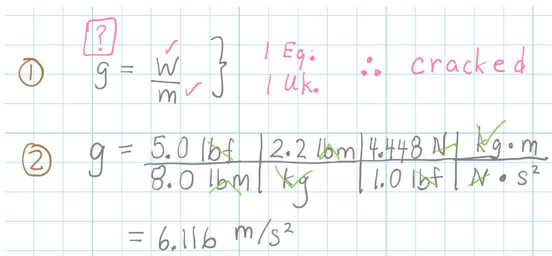
On planet Y, an 8 lbm object weighs 5 lbf on a spring balance. In units of m/s^2, what is the value of g on planet Y?

(a) 14.7 (b) 13.0 (c) 15.7 (d) 9.8 (e) 6.1

Feedback

Claim: The best answer is (e)

Reasoning:



The steps are:

1. Apply the weight equation
2. Do the calculation

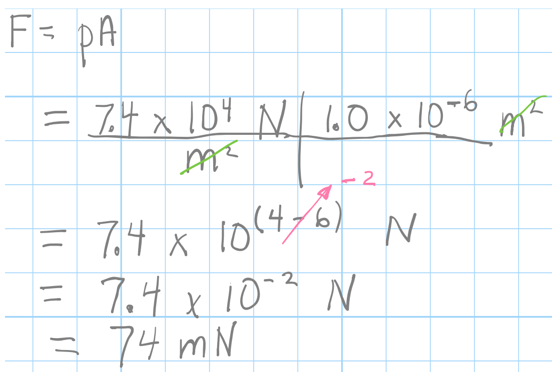
Problem 1.5

If $F = pA$, $p = 74\,000\,\text{Pa}$, and $A = 1\text{e-}06\ \text{m}^2$, then the force F is:
(a) $74\,\text{mN}$ (b) $0.0074\,\text{N}$ (c) $740\,\mu\text{N}$ (d) $74\,\mu\text{N}$ (e) $74 \times 10^{-5}\,\text{N}$

Feedback

Claim: The best choice is (a)

Reasoning:



Problem 1.6

What is the weight in kN of a spa that is filled with 1500 L of water? The mass of the spa when it is empty is 250 kg.

(a) 13 (b) 15 (c) 17 (d) 21 (e) 23

Feedback

Claim: Answer (c) is the best choice.

Reasoning:

$$\boxed{17}$$

$$W = mg + \gamma V$$

$$\cong \frac{250\ \text{kg}}{} \left| \frac{9.81\ \text{N}}{\text{kg}} \right. + \frac{9800\ \text{N}}{\text{m}^3} \left| \frac{1.5\ \text{m}^3}{} \right.$$

$$\cong 17.2\ \text{kN} \approx 17\ \text{kN}$$

Problem 1.7

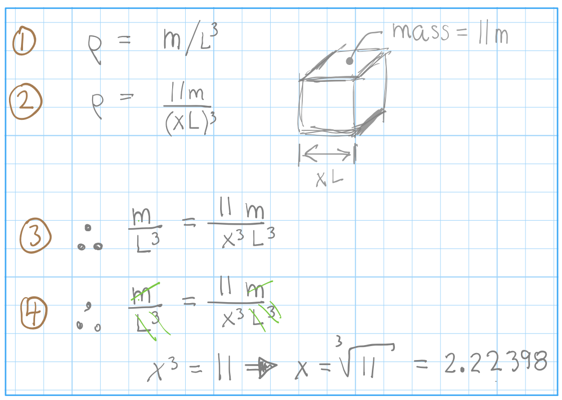
A fluid tank in the shape of a cube holds a mass m of a liquid. Each side of the tank has a length L. What length is required to hold 11 times as much mass of the same liquid, also in a cube shaped tank?

(a) $1.14L$ (b) $2.22L$ (c) $3.67L$ (d) $4.91L$ (e) $2.83L$

Feedback

Claim: The best choice is (b)

Reasoning:



The steps are

1. Apply the definition of density to the small cube
2. Apply the definition of density to the large cube
3. Combine Eqs. (1) and (2)
4. Solve for the length multiplier x

Problem 1.8

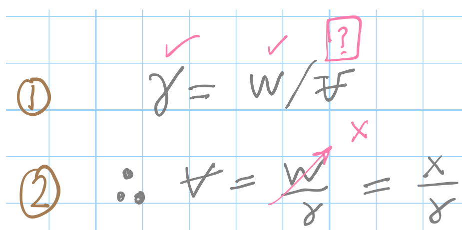
A tank holds $x = 12\,\text{kN}$ of a liquid. What formula gives the volume of the tank?

a. γ/x
b. x/γ
c. γx
d. $1/(\gamma x)$
e. $x\gamma/\rho$

Feedback

Claim: The best choice is (b)

Reasoning:



The steps are:

1. Apply the definition of specific weight
2. Solve for volume

Problem 1.9

(T/F) If nitrogen in a steel tank is heated, then the density of the nitrogen will decrease.

Feedback

The best answer is false. The reasoning follows.

1. Average density is mass/volume: $\rho = m/V$
2. When the tank is heated, the mass of nitrogen does not change.
3. Also, the volume of the tank does not change (ignore the tiny expansion of the steel).
4. Therefore, the density will stay constant.

1.10: PROBLEM DEFINITION

Situation:
Methane gas.

Find:
Density (kg/m^3).

Properties:
From Table A.2 (EFM12e), $R_{\text{Methane}} = 518 \ \frac{\text{J}}{\text{kg} \cdot \text{K}}$
$p = 200\,\text{kPa}$, $T = 80\,^\circ\text{C}$.

PLAN

1. Apply the ideal gas law to find density.

SOLUTION

1. Ideal gas law

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

$$\boxed{\rho_{\text{Methane}} = 1.09 \ \text{kg/m}^3}$$

REVIEW

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

1.11: PROBLEM DEFINITION

Situation:

Wind and water

$T = 100\,^\circ\text{C}$; $p = 4\,\text{atm} = 405,200\,\text{Pa}$.

Find:

Ratio of density of water to density of air.

Properties:

Air, Table A.2 (EFM12e): $R_{\text{air}} = 287$ J/kg·K.

Water (100°C), Table A.5: $\rho_{\text{water}} = 958$ kg/m^3.

PLAN

Apply the ideal gas law to air.

SOLUTION

Ideal gas law

$$\begin{aligned}\rho_{\text{air}} &= \frac{p}{RT} \\ &= \frac{405,200\,\text{Pa}}{(287\,\text{J/ kg K})\,(100+273)\,\text{K}} \\ &= 3.785 \text{ kg/m}^3\end{aligned}$$

For water

$$\rho_{\text{water}} = 958 \text{ kg/m}^3$$

Ratio

$$\frac{\rho_{\text{water}}}{\rho_{\text{air}}} = \frac{958\,\text{kg/ m}^3}{3.785\,\text{kg/ m}^3}$$

$$\boxed{\frac{\rho_{\text{water}}}{\rho_{\text{air}}} = 253}$$

REVIEW

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

1.12: PROBLEM DEFINITION

Apply the grid method.

<u>Situation</u>:

Density of ideal gas is given by:

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

$p = 60$ psi, $R = 1716\,\text{ft} \cdot \text{lbf}/\,\text{slug} \cdot {}^\circ\text{R}$.
$T = 180\,^\circ\text{F} = 640\ \ {}^\circ\text{R}$.

<u>Find</u>:

Calculate density (in lbm/ft^3).

PLAN

Use the definition of density.
Follow the process for the grid method given in the text.
Look up conversion formulas in Table F.1 (EFM12e).

SOLUTION

(Note, cancellation of units not shown below, but student should show cancellations on handworked problems.)

$$\begin{aligned}\rho &= \frac{p}{RT} \\ &= \left(\frac{60\,\text{lbf}}{\text{in}^2}\right)\left(\frac{12\,\text{in}}{\text{ft}}\right)^2\left(\frac{\text{slug}\cdot{}^\circ\text{R}}{1716\,\text{ft}\cdot\,\text{lbf}}\right)\left(\frac{1.0}{640\ {}^\circ\text{R}}\right)\left(\frac{32.17\ \text{lbm}}{1.0\,\text{slug}}\right)\end{aligned}$$

$$\boxed{\rho = 0.253\ \ \text{lbm}/\,\text{ft}^3}$$

Problem 1.13

The dimensions of mass are:
(a) FL/T^2 (b) FT^2/L (c) FL/T (d) FT/L (e) FT/L^2

Feedback

Claim: The best choice is (b)

Reasoning:

(1) $\sum F = ma$

(2) $\therefore \quad [F] = ML/T^2$

(3) $\therefore \quad M = \frac{T^2}{L} F$

The steps are:

1. Start with a true equation (Newton's second law)
2. List the dimensions of each variable in the equation
3. Solve for the dimensions of mass

1.14: PROBLEM DEFINITION

Situation:

The power provided by a centrifugal pump is given by:

$$P = \dot{m}gh$$

Find:

Prove that the above equation is dimensionally homogenous.

PLAN

1. Look up primary dimensions of P and $\dot{m}$ using Table F.1 (EFM12e).
2. Show that the primary dimensions of P are the same as the primary dimensions of $\dot{m}gh$.

SOLUTION

1. Primary dimensions:

$$\begin{aligned} [P] &= \frac{M \cdot L^2}{T^3} \\ [\dot{m}] &= \frac{M}{T} \\ [g] &= \frac{L}{T^2} \\ [h] &= L \end{aligned}$$

2. Primary dimensions of $\dot{m}gh$:

$$[\dot{m}gh] = [\dot{m}]\,[g]\,[h] = \left(\frac{M}{T}\right)\left(\frac{L}{T^2}\right)(L) = \frac{M \cdot L^2}{T^3}$$

Since $[\dot{m}gh] = [P]$, **The power equation is dimensionally homogenous.**

Appendix A

Methods for Active Learning in Engineering Classes

Introduction

We have provided some active learning methods for your use because your students will learn more and their levels of engagement will increase.*

Active learning is defined here as having students engage in activities that require critical thinking anc collaboration. The talking/defending components described below will increase student engagement and focus (as compared to being a passive note-taker) in the valuable time when they are in the presence of you, the professor.

I. Team Peer Assessment of Student Work

Rationale. Increase student ownership. Improve students ability to recognize and perform quality technical work.

1. Select a task that is due.
2. Put students in teams of 2, 3, or 4.
3. Have each student in the team present their work to their peers and explain what aspects of the work are done well.
4. Have the team select the work that represents the best of the team and justify why.
5. Have a spokesman from 1 or 2 teams present the work that they found to be the highest quality to the rest of the class.

II. Clicker or "Vote" Classroom Problems

Rationale. Develop skills for self-assessment wherein students perform reasoning, test their reasoning, and correct mis-conceptions.

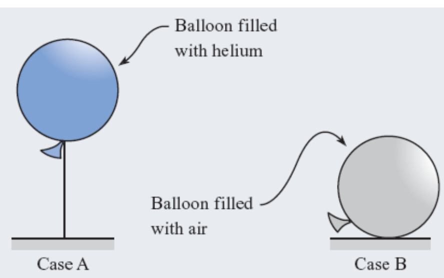
1. Present a conceptual problem on the board with at least 2 multiple choice answers. Consider this example:

Consider a balloon filled with helium (case A) and a balloon filled with air (case B). Which statement is correct?

a. Buoyant force (case A) > Buoyant force (case B)

b. Buoyant force (case A) < Buoyant force (case B)

c. Buoyant force (case A) = Buoyant force (case B)



2. Prepare "distractor" choices that are plausible to novice learners, and can be used to highlight critical elements of a concept (as in the example).

3. Have students discuss the problem in pairs of 2 (optional).
4. Have the class "vote" for what they believe to be the correct choice, either with clickers, or a show of hands.
5. Report exact (clicker) or approximate counts (hands) to the class.
6. Discuss why one answer is correct, and why other answers may seem correct, but are not. If time allows, do this as a class discussion, allowing students to "defend their position". If time is limited, do this yourself.
7. If the 2nd-most-selected choice has part of the correct concept, but not all of it, coach the students to understand how they were "almost right", but how they need to articulate and reject the flawed assumption that allowed them to reach an incorrect conclusion.

III. **Identifying What Students are Doing Well - Engineering Skills**

Rationale. Have student understand and take ownership of skills for doing engineering well.
1. (5 to 10 minutes, before class). Skim your student's homework and identify specific things (e.g. documentation, canceling and carrying units, defining knowns and unknowns, sketch, logical reasoning, etc.) that you think are well done. Make a list of about 8 items.
2. (2 to 4 minutes at the start of next class) Ask your students to select the top two items off the list (e.g., ask them, which 2 item represent the best engineering practices) and to explain why they made these choices. Then direct the students to find a partner, and have them present their findings to a partner and have the student and the partner select their top two as a team. Call on a few students so you can hear what students have come up with.

***NOTE:** You may want to solicit the support of an experienced faculty member who is interested in engineering education if you have not employed active learning before. In your institution, active learning may be novel for engineering students, and you may receive some push-back. Research indicates, however, that active learning, if well-implemented, leads to better performance on exams, and in post-graduate careers.