Prof. White's pickup truck weighs about 100 lbf more when the fuel tank is full versus when it is empty. If the specific gravity of gasoline is about 0.726 and the price of gas is about $2.30 per gallon, estimate the maximum cost to "fill it up".

— — — —

$$W = mg = \rho V g = \rho g V = \gamma V$$

sp. wt.

$$sg = \frac{\gamma_{fluid}}{\gamma_{water\ at\ 4C}} = \frac{\rho_{fluid}}{\rho_{w\ at\ 4C}}$$

specific gravity

$$\therefore \quad \gamma_{fluid} = sg\,\gamma_{water\ at\ 4C} = (0.726)\left(62.4\ \frac{lbf}{ft^3}\right) = 45.30\ \frac{lbf}{ft^3}$$

$$\text{and} \quad V = \frac{W}{\gamma} = \frac{100\ lbf}{45.30\ \frac{lbf}{ft^3}}$$

$$= 2.207\ ft^3 \times 7.48\ \frac{gal}{ft^3} = 16.51\ gal$$

$$\text{cost} = 16.51\,gal \times \frac{\$2.30}{gal} = \$37.98$$

$\sim \$38$ ans

Hibbler
Prob 1.15

Ideal Gas Law

A tank contains air at a temperature of 15 C and an absolute pressure of 210 kPa. The volume of the tank is 5 $m^3$. If the temperature of the air rises to 30 C, determine the mass of air that must be removed from the tank to maintain the same initial pressure.

---

Initial state $\quad P_1 = 210\,kPa \quad T_1 = 15 + 273 = 288\,K$

$V_1 = 5\,m^3$

$PV = mRT \qquad m_1 = \left.\frac{PV}{RT}\right)_1 = \frac{\left(210\times10^3 \frac{N}{m^2}\right)(5\,m^3)}{\left(286.9 \frac{N\text{-}m}{Kg\text{-}K}\right)(288\,K)}$

$P = \rho R T$

where $\rho = \frac{m}{V}$

$= 12.708\,kg$

Final state $\quad P_2 = 210\,kPa \quad T_2 = 30 + 273 = 303\,K$

$V_2 = 5\,m^3$

$\therefore \quad m_2 = \left.\frac{PV}{Rt}\right)_2 = \frac{(210\times10^3)(5)}{(286.9)(303)}$

$= 12.078\,kg$

$\therefore \quad \Delta m = m_1 - m_2$

$= 12.708 - 12.078$

$= \boxed{0.63\,kg}$ ans

0.63 kg must be removed to maintain constant pressure

White 4th Ed

Units

1.13 The efficiency $\eta$ (dimensionless) of a pump is defined as the ratio of the power delivered to the fluid to the power required to drive the pump.

$P_A$ - power added
$P_I$ - power input

$$\eta = \frac{P_A}{P_I} = \frac{Q\,\Delta p}{P_I}$$

where Q is the volume flow rate and $\Delta p$ is the pressure rise produced by the pump.

Suppose that a certain pump develops a pressure rise of 35 psi when its flow rate is 40 L/s. If the input power is 16 hp, what is the pump efficiency?

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This problem involves proper units conversion.

Let's choose $\boxed{\text{SI units}}$ as the base

$$\therefore\ Q = 40\ L/s \times \frac{1\ m^3}{1000\ L} = 0.04\ m^3/s$$

$$\Delta p = 35\ psi * \frac{6895\ Pa}{psi} = 2.413\times10^5\ Pa = 2.413\times10^5\ \frac{N}{m^2}$$

$$\frac{101.33\ Pa}{14.696\ psi} = 6895\ \frac{Pa}{psi}$$

$$P_A = Q\,\Delta p = 0.04\ \frac{m^3}{s} * 2.413\times10^5\ \frac{N}{m^2} = 9653\ \frac{N\text{-}m}{s} = 9653\ \frac{J}{s}$$

$$\boxed{P_A = 9653\ W}$$

$$P_I = 16\ hp \times 745.7\ \frac{W}{hp} = \boxed{11931\ W}$$

$$\therefore\ \eta = \frac{P_A}{P_I} = \frac{9653\ W}{11931\ W} = \boxed{0.809}$$

$$\boxed{\eta \simeq 81\%}$$

→ also could convert to another set of units

Unit consistency

The velocity profile for a moving fluid near the surface of a flat plate can often be described with a quadratic relationship of the form

$$u(y) = c_1 y + c_2 y^2$$

where y is the distance from the plate surface and u is the fluid velocity. In a particular situation, $u = 10y - 0.25y^2$, where y is in mm and u has units of mm/s. For this situation, what are the units of the constants $c_1 = 10$ and $c_2 = -0.25$?

---

$$u = c_1 y + c_2 y^2$$

every term must have the same units

$$\therefore \quad \frac{mm}{s} = (s^{-1})(mm) + (mm^{-1}s^{-1})(mm^2)$$

$$\therefore \quad \boxed{c_1 \text{ units} \rightarrow s^{-1} = \frac{1}{s}}$$ ← ans

and

$$\boxed{c_2 \text{ units} \rightarrow mm^{-1}s^{-1} = \frac{1}{mm-s}}$$

Munson
3rd Ed



reword slightly

[1.8] The force, F, that is exerted on a spherical particle moving slowly through a liquid is given by

$$F = 3\pi \mu D v$$

where $\mu$ is the fluid viscosity, D is the particle diameter, and v is the particle velocity. What are the units of the constant $3\pi$? Can this equation be used with both English and SI units? Explain

---

pick SI units

$$N \Rightarrow C \left(\frac{N\text{-}s}{\cancel{m^2}}\right)\left(\cancel{m}\right)\left(\frac{\cancel{m}}{\cancel{s}}\right)$$

$$N \Rightarrow C\,(N) \qquad \therefore \text{ C is dimensionless}$$

$\therefore$ the equation is valid for both English and SI units.

if we had picked English units

$$lbf \Rightarrow C \left(\frac{lbf - \cancel{s}}{\cancel{ft^2}}\right)\left(\cancel{ft}\right)\left(\cancel{ft}/\cancel{s}\right)$$

$$lbf \Rightarrow C\,(lbf) \qquad \therefore \text{ C is dimensionless}$$

as above

$\boxed{1.37}$ A compressed air tank contains 8 kg of air at a temperature of 80°C. A gage on the tank reads 300 kPa. Determine the volume of the tank.

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$$\text{volume} = \frac{\text{mass}}{\text{density}} = \frac{m}{\rho}$$

$m = 8$ kg of air (given)

$$\rho = \frac{P}{RT} \qquad \text{(ideal gas law)}$$

$R_{air} = 286.9 \ J/kg\text{-}K$   { Table 1.8 Munson, App A Hibbeler

$\quad = 286.9 \ N\text{-}m/kg\text{-}K$

$T_{abs} = 80 + 273 = 353 \ K$

$P_{abs} = P_{gage} + P_{atm}$

$\quad = 300 \ kPa + 101.3 \ kPa = 401.3 \ kPa$

$\quad = 401.3 \times 10^3 \ N/m^2$

$$\therefore \ \rho_{air} = \frac{401.3 \times 10^3 \ N/m^2}{\left(286.9 \ \frac{N\text{-}m}{kg\text{-}\cancel{K}}\right)(353 \ \cancel{K})} = 3.961 \ kg/m^3$$

Finally

$$\text{Vol tank} = \frac{m}{\rho} = \frac{8 \ kg}{3.961 \ kg/m^3} = \boxed{2.02 \ m^3}$$

ans