 Name Solution

15% **1.** A mercury-filled (density of mercury = 13560 kg/m^3) U-tube is connected to a pressurized tank. The atmospheric pressure is 1 atm. If the difference in the height of the mercury level in each side of the U-tube is 200 mm, what is the pressure in the tank, in kPa? **Show your work.**

+1 $L = 200\ mm$

+1 $P_o = 1\ atm$

+1 $g = 9.80665\ \frac{m}{s^2}$

+1 $\rho = 13560\ \frac{kg}{m^3}$

+3 $\Delta P = P - P_o = \rho L g$

$= (13560\ \frac{kg}{m^3})(200mm)(9.80665\ \frac{m}{s^2}) \cdot \frac{1m}{10^3 mm} \cdot \frac{1N}{1\frac{kg\,m}{s^2}} \cdot \frac{1kPa}{10^3 \frac{N}{m^2}}$

+4 $\Delta P = 26.596\ kPa$

$\Delta P = P - P_o$

$P = \Delta P + P_o = 26.596\ kPa + 1atm \cdot \frac{101.325\ kPa}{1atm} = \boxed{127.9\ kPa = P}$

+4

10% **2.** Dr. Hruda's January electric bill said she used 237 kW-h (kilowatt hours). Convert this energy into J (joules).

+3 +2

$237\ kW \cdot h \cdot \frac{60 min}{1 hr} \cdot \frac{60 sec}{1 min} \cdot \frac{10^3 \frac{J}{s}}{1 kW} =$

$853.2 \times 10^6\ J = \boxed{8.532 \times 10^8\ J} = 853.2\ MJ$

+5

in kJ -1

SPH

25

10/10

3. Kinetic energy is $KE = \frac{1}{2}mv^2$, where m is mass, and v is velocity. Calculate the kinetic energy in kJ (kilojoules) of a 3086 lbm (1400 kg) car traveling at 55 miles per hour.

$m = 1400 \text{kg}$ $\quad v = 55 \frac{mi}{h}$

+2 $KE = \frac{1}{2} m v^2$

$$= \frac{1}{2}(1400 \text{ kg})\left(55 \frac{mi}{h}\right)^2 \cdot \left(\frac{1 \frac{m}{s}}{2.237 \frac{mi}{h}}\right)^2 \cdot \frac{1 N}{1 \frac{kg\, m}{s^2}} \cdot \frac{1 kJ}{10^3 Nm}$$

+2 +2

$$\boxed{KE = 423 \text{ kJ}}$$

+4

in J −1
bad units −2
bad math −2

$$55 \frac{mi}{h} \cdot \frac{1.609 \frac{km}{h}}{1 \frac{mi}{h}} \cdot \frac{1 \frac{m}{s}}{3.60 \frac{km}{h}} = 24.58 \frac{m}{s}$$

35% **4.** There is a new element **Petersonium (Pe)**.

5 (a) If Petersonium has $R = 0.1812 \frac{kJ}{kgK}$

What is its molecular mass?

$$R = \frac{\bar{R}}{M} \Longrightarrow M = \frac{\bar{R}}{R} \quad +2$$

$$= \frac{8.314 \frac{kJ}{kmol\,K}}{0.1812 \frac{kJ}{kg\,K}}$$

$$\boxed{M = 45.883 \frac{kg}{kmol}} \quad +3$$

-1 bad math

7 (b) Assuming ideal gas behavior, what is the specific volume of Petersonium at **800°C**, **8 kPa**?

$T = 800°C + 273 = 1073\,K$ +1

$P = 8\,kPa$

$\nu = ?$

$$P\nu = RT \Longrightarrow \nu = \frac{RT}{P} \quad +2$$

$$\nu = \frac{(0.1812 \frac{kJ}{kgK})(1073K)}{8\,kPa} \cdot \frac{1\,kPa}{10^3 \frac{N}{m^2}} \cdot \frac{10^3\,Nm}{1\,kJ}$$

$$\boxed{\nu = 24.30 \frac{m^3}{kg}} \quad +4$$

7 (c) Assuming ideal gas behavior, what is the mass of **400 L** of Petersonium at **800°C**, **8 kPa**?

$V = 400\,L$

$m = ?$

$T = 800°C + 273 = 1073\,K$ +1

$P = 8\,kPa$

$$PV = mRT \Longrightarrow m = \frac{PV}{RT} \quad +2$$

$$m = \frac{(8\,kPa)(400\,L)}{(0.1812 \frac{kJ}{kgK})(1073K)} \cdot \frac{1\,kJ}{10^3\,Nm} \cdot \frac{10^3 \frac{N}{m^2}}{1\,kPa} \cdot \frac{1\,m^3}{10^3\,L}$$

$$\boxed{m = 0.01646\,kg}$$

+4

or

$$\nu \equiv \frac{V}{m}$$

$$m = \frac{V}{\nu}$$

$$= \frac{400\,L}{24.30 \frac{m^3}{kg}} \cdot \frac{1\,m^3}{10^3\,L}$$

$$\boxed{m = 0.01646\,kg}$$

4. continued

7 (d) A **1500 L** tank contains **2 kg** of Petersonium at **1200°C**. What is the pressure in the tank (assuming ideal gas behavior)?

$V = 1500\,L$

$m = 2\,kg$

$T = 1200°C + 273 = 1473\,K$ +1

$P = ?$

$PV = mRT \longrightarrow P = \frac{mRT}{V}$ +2

$$P = \frac{(2kg)(0.1812 \frac{kJ}{kg\,K})(1473\,K)}{1500\,L} \cdot \frac{10^3 L}{1 m^3} \cdot \frac{10^3 Nm}{1 kJ} \cdot \frac{1 kPa}{10^3 \frac{N}{m^2}}$$

$\boxed{P = 355.9\,kPa}$ +4

9 (f) If the pressure found in **part (e)** was measured using a U-tube with one end exposed to atmospheric pressure (1 atm), and filled with a substance having **density = 54321 kg/m³**, what would the difference in column height be?
*(If you could not complete part (e), assume the pressure is **500 kPa**.)*

$\Delta P = \rho L g$ +2

$P = 355.9\,kPa$

$P_0 = 1\,atm = 101.325\,kPa$ +1

$\rho = 54321 \frac{kg}{m^3}$

$g = 9.80665 \frac{m}{s^2}$

$L = \frac{\Delta P}{\rho g} = \frac{P - P_0}{\rho g}$ +2

$$= \frac{(355.9\,kPa - 101.325\,kPa)}{(54321 \frac{kg}{m^3})(9.80665 \frac{m}{s^2})} \cdot \frac{10^3 \frac{N}{m^2}}{1 kPa} \cdot \frac{1 \frac{kg\,m}{s^2}}{1N}$$

$\boxed{L = 0.4778\,m = 477.8\,mm}$

bad math -2
bad conversion -2
not shown -4

+4

if P = 500 kPa

$$L = \frac{(500kPa - 101.325kPa)}{(54321 \frac{kg}{m^3})(9.80665 \frac{m}{s^2})} \cdot \frac{10^3 \frac{N}{m^2}}{kPa} \cdot \frac{1 \frac{kg\,m}{s^2}}{1N} = \boxed{0.7484\,m \\ 748\,mm} = L$$

SPH

30/35 **5.** Air is initially at 32°F, and a pressure of 1 atm. A lightning bolt passes through the air heating it to 20,000°C, and the pressure is unchanged.
Assume constant pressure and ideal gas behavior for the air.

5 **(a)** Sketch pictures of a quantity of air before and after the lightning bolt strikes, and write the given information under each picture.

5 **(b)** What is the initial temperature of the air in °C?

8 **(c)** What is the initial specific volume of the air?

6 **(d)** What is the specific volume of the air immediately after being heated by the lightning bolt?

6 **(e)** If percent change is defined to be

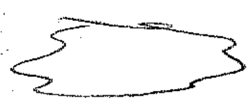
$$\frac{\textit{final value} - \textit{initial value}}{\textit{initial value}} * 100$$

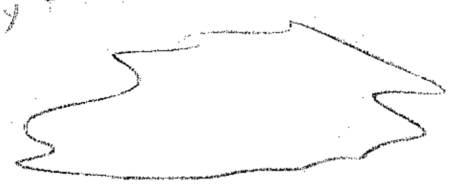
what is the percent change in the specific volume of the air as the lightning bolt passes?

Show all work, and specify tables used!

DO NOT WRITE ABOVE THIS LINE!

(a) ①　　　+2 only pictures　　　②





+1 $T_1 = 32°F$

+1 $P_1 = 1 atm$

+1 $T_2 = 20000°C + 273 = 20273 K$

$P_2 = P_1 = 1 atm$

(b) $T_1 = 32°F$

$°C = (°F - 32)\frac{5}{9}$

$= (32°F - 32)\frac{5}{9} = \boxed{0°C = T_1} = 0°C + 273 = 273 K$ +5

(c) $P_1 v_1 = RT_1$　　$R_{air} = 0.2870 \frac{kJ}{kg K}$ (table B-2) +2

$v_1 = \frac{RT_1}{P_1}$ +2

$= \frac{(0.2870 \frac{kJ}{kg K})(273 K)}{1 atm} \cdot \frac{1 atm}{101.325 kPa} \cdot \frac{1 kPa}{10^3 \frac{N}{m^2}} \cdot \frac{10^3 Nm}{1 kJ}$

$\boxed{v_1 = 0.7733 \frac{m^3}{kg}}$ +4

(d) $P_2 \nu_2 = R T_2$

$$\nu_2 = \frac{R T_2}{P_2} \quad +2$$

$$= \frac{(0.2870 \frac{kJ}{kgK})(20273 K)}{1 atm} \cdot \frac{1 atm}{101.325 kPa} \cdot \frac{1 kPa}{10^3 \frac{N}{m^2}} \cdot \frac{10^3 Nm}{1 kJ}$$

$$\boxed{\nu_2 = 57.42 \frac{m^3}{kg}} \quad +4$$

– OR –

$$P_2 \nu_2 = R T_2 \implies \frac{\nu_2}{T_2} = \frac{R}{P_2} \quad P_2 = P_1 \longrightarrow \frac{\nu_2}{T_2} = \frac{\nu_1}{T_1}$$

$$\nu_2 = \frac{\nu_1}{T_1} T_2$$

$$\nu_2 = \frac{(0.7733 \frac{m^3}{kg})(20273 K)}{(273 K)} = \boxed{57.42 \frac{m^3}{kg} = \nu_2}$$

(e) $$\% \text{ change} = \frac{\nu_2 - \nu_1}{\nu_1} * 100 \quad +2$$

$$= \frac{(57.42 \frac{m^3}{kg} - 0.7733 \frac{m^3}{kg})}{(0.7733 \frac{m^3}{kg})} * 100$$

$$\boxed{\% \text{ Change} = 7326\%}$$

+4

10%

BONUS: The gravitational acceleration on the planet Jupiter is 23.1 m/s^2.
Calculate the mass of a 6 meter diameter solid copper sphere on Jupiter.

Element	Density (g/cm^3)
Aluminum	2.70
Copper	8.92
Gold	19.3
Iron	7.86
Silver	10.5

$g = 23.1 \frac{m}{s^2}$

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

$V_{sphere} = \frac{4}{3}\pi r^3$

$d = 6m$

$r = \frac{d}{2} = 3m$

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

$V = 113.1 \, m^3$

$m = \rho V$

$= \left(8.92 \frac{g}{cm^3}\right)(113.1 \, m^3) \cdot \left(\frac{10^2 \, cm}{1m}\right)^3 \cdot \frac{1 \, kg}{10^3 \, g}$

$m = 1.009 \times 10^6 \, kg$

$= 1,008,852 \, kg$

$= 1.009 \times 10^9 \, g$

Useful Equations

interpolation: $y_m = y_1 + \frac{(y_2 - y_1)}{(x_2 - x_1)}(x_m - x_1)$

$\Delta P = \rho L g$

$x = \frac{m_g}{m_f + m_g}$

$\bar{v} = \frac{V}{n}$

$PV = mRT$

$v = v_f + x v_{fg}$

$v = \frac{V}{m}$

$Pv = RT$

$v_{fg} = v_g - v_f$

$PV = n\bar{R}T$

$V(sphere) = \frac{4}{3}\pi r^3$

$P_r = \frac{P}{P_c}$

$V(cylinder) = \pi r^2 h$

$F = ma$

$T_r = \frac{T}{T_c}$

$F = \frac{ma}{g_c}$

$F = \frac{9}{5}{}^{o}C + 32$

$K = {}^{o}C + 273$

$R = F + 460$