Lecture Problems
Chapter 12, sec 1-2

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Boyle's Law. $PV = C_B$ A Chevy large block engine has a volume of 350 in^3. If the engine has a compression ratio of 10:1, the initial pressure is 1 atm and the final pressure during the piston cycle is 10 atm. What is the volume of the compressed air?

Given

$V_1 := 350 \cdot in^3$ $P_1 := 1 \cdot atm$ $P_2 := 10 \cdot atm$

Conversions (Optional)

$$V_1 \cdot \left(\frac{1 \cdot in}{2.54 \cdot cm}\right)^3 \cdot \left(\frac{1 \cdot cm^3}{1 \cdot mL}\right) \cdot \left(\frac{1 \cdot mL}{10^{-3} \cdot liter}\right) = 5.7354724 \cdot liter \qquad V_1 = 0.00573547 \cdot m^3$$

$$P_1 \cdot \left(\frac{101325 \cdot Pa}{1 \cdot atm}\right) = 1.01325 \cdot 10^5 \cdot Pa$$

$$P_2 \cdot \left(\frac{101325 \cdot Pa}{1 \cdot atm}\right) = 1.01325 \cdot 10^6 \cdot Pa$$

Calculate Constant

$C := P_1 \cdot V_1$ $C = 350 \cdot atm \cdot in^3$

$V_2 := \frac{C}{P_2}$ $V_2 = 35 \cdot in^3$

Ratio Method:

$V_1 \cdot P_2 = C$

$V_2 \cdot P_2 = C$

$V_1 \cdot P_1 = V_2 \cdot P_2$

$V_2 := \frac{V_1 \cdot P_1}{P_2}$

$V_2 = 35 \cdot in^3$

Pressure and Temperature. A pressure cooker is sealed at 1 atm and 25 C. What is the pressure at 200 C?

Given:

$P_1 := 1 \cdot atm$ $T_1 := (273.15 + 25) \cdot K$ $T_2 := (273.15 + 200) \cdot K$

Ratio:

$$\frac{P_1}{T_1} = 0.00335402 \cdot atm \cdot K^{-1}$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$P_2 := \frac{P_1}{T_1} \cdot T_2$ $P_2 = 1.58695288 \cdot atm$

Charles Law. 1 m^3 of steam is heated from 100 C to 500 C at constant pressure. What is the final volume?

Given:

$V_1 := 1 \cdot m^3$ $T_1 := (273.13 + 100) \cdot K$ $T_2 := (273.15 + 500) \cdot K$

Calculate:

$$\frac{V_1}{T_1} = 0.00268003 \cdot m^3 \cdot K^{-1}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$V_2 := \frac{V_1}{T_1} \cdot T_2$

$V_2 = 2.07206604 \cdot m^3$

When the piston of a steam engine contains 5 pounds of steam the pressure is 125 psi. What is the pressure in the piston if 15 pounds of steam is added?

Given:

$n_1 := 5 \cdot lb \qquad P_1 := 125 \cdot psi \qquad n_2 := 15 \cdot lb$

Conversions (Not Nessicary)

$MW := 18 \cdot gm \cdot mole^{-1}$

$$n_1 \cdot \left(\frac{453.59237 \cdot gm}{lb} \right) \cdot \left(\frac{1 \cdot mole}{18 \cdot gm} \right) = 125.99788056 \cdot mole$$

$$n_2 \cdot \left(\frac{453.59237 \cdot gm}{lb} \right) \cdot \left(\frac{1 \cdot mole}{18 \cdot gm} \right) = 377.99364167 \cdot mole$$

$$P_1 \cdot \left(\frac{1 \cdot atm}{14.6959 \cdot psi} \right) \cdot \left(\frac{101325 \cdot Pa}{1 \cdot atm} \right) = 8.61847522 \cdot 10^5 \cdot Pa$$

Ratio:

$$\frac{P_1}{n_1} = 25 \cdot psi \cdot lb^{-1}$$

$$\frac{P_1}{n_1} = \frac{P_2}{n_2}$$

$P_2 := \frac{P_1}{n_1} \cdot n_2 \qquad P_2 = 375 \cdot psi$

Combined Gas Law. A stratospheric sampling balloon starts at sea level, 760 torr and 20 C with a volume of 1000 m^3. The balloon rises to a pressure altitude of 1000 Pa (appx 40 km) where the temperature is -40 C. What is the volume of the balloon at this altitude?

$P_1 := 760 \cdot torr$ $P_2 := 1000 \cdot Pa$

$T_1 := (273.15 + 20) \cdot K$ $T_2 := (273.15 - 40) \cdot K$

$V_1 := 1000 \cdot m^3$

Conversions (must have same units)

$$P_1 \cdot \left(\frac{1 \cdot atm}{760 \cdot torr}\right) \cdot \left(\frac{101325 \cdot Pa}{1 \cdot atm}\right) = 1.01325 \cdot 10^5 \cdot Pa$$

Calculations:

$$\frac{P_1 \cdot V_1}{T_1} = 3.45641208 \cdot 10^5 \cdot Pa \cdot m^3 \cdot K^{-1}$$

$$\frac{P_1 \cdot V_1}{T_1} = \frac{P_2 \cdot V_2}{T_2}$$

$$V_2 := \left(\frac{P_1 \cdot V_1}{T_1}\right) \cdot \left(\frac{T_2}{P_2}\right)$$

$$V_2 = 8.05862475 \cdot 10^4 \cdot m^3$$

Calculate the molar volume given the volume for 1 gram of gas at STP.

$mass := 1 \cdot gm \qquad T := 273.15 \cdot K \qquad P := 10^5 \cdot Pa$

For H_2:

$V := 11.1 \cdot liter$

$MW := (2 \cdot 1.007) \cdot gm \cdot mole^{-1}$

$V_{mole} := V \cdot \frac{MW}{mass} \qquad V_{mole} = 22.3554 \cdot liter$

For He:

$V := 5.57 \cdot liter$

$MW := (4.0026) \cdot gm \cdot mole^{-1}$

$V_{mole} := V \cdot \frac{MW}{mass} \qquad V_{mole} = 22.294482 \cdot liter$

For N_2:

$V := 0.800 \cdot liter$

$MW := (2 \cdot 14.007) \cdot gm \cdot mole^{-1}$

$V_{mole} := V \cdot \frac{MW}{mass} \qquad V_{mole} = 22.4112 \cdot liter$

For Cl_2:

$V := 0.316 \cdot liter$

$MW := (2 \cdot 35.4525) \cdot gm \cdot mole^{-1}$

$V_{mole} := V \cdot \frac{MW}{mass} \qquad V_{mole} = 22.40598 \cdot liter$