Date : 26/07/23 Lecture 4 Unitd and Dimensions

Topics:

(1) standard systems of units: CGS, MKS, FPS & SI

(2) Units of mass, length, energy and temperature.

Unit conversions: (lb = pound)

1 lb = 453 g

1 kg = 2.2 lb

1 in = 2.54 cm = 25.4 mm

1 ft = 30 cm

1 hp = 746 Watt

1 cal = 4.18 J

1 Btu = 1055 J

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Temperature units: Lecture-5

$$\frac{C}{5} = \frac{F-32}{9} = \frac{K-273.15}{5} = \frac{R-491.7}{9}$$

$$1\Delta °C = 1.8\Delta °F$$

$$1\Delta K = 1.8\Delta R$$

Absolute temperature scales: start from 0 value.
eg. Kelvin and Rankine

Relative temperature scales: Celcius and Fahrenheit

Reference points: Constant (thermodynamic) states

Lower fixed point: Freezing point of water: $0°C = 32°F = 273.15K = 492°R$

Upper fixed point: Boiling point of water: $100°C = 212°F = 373.15K = 672°R$

Pressure scales:

Absolute pressure (value above zero pressure)

Relative pressure: with respect to atmospheric pressure

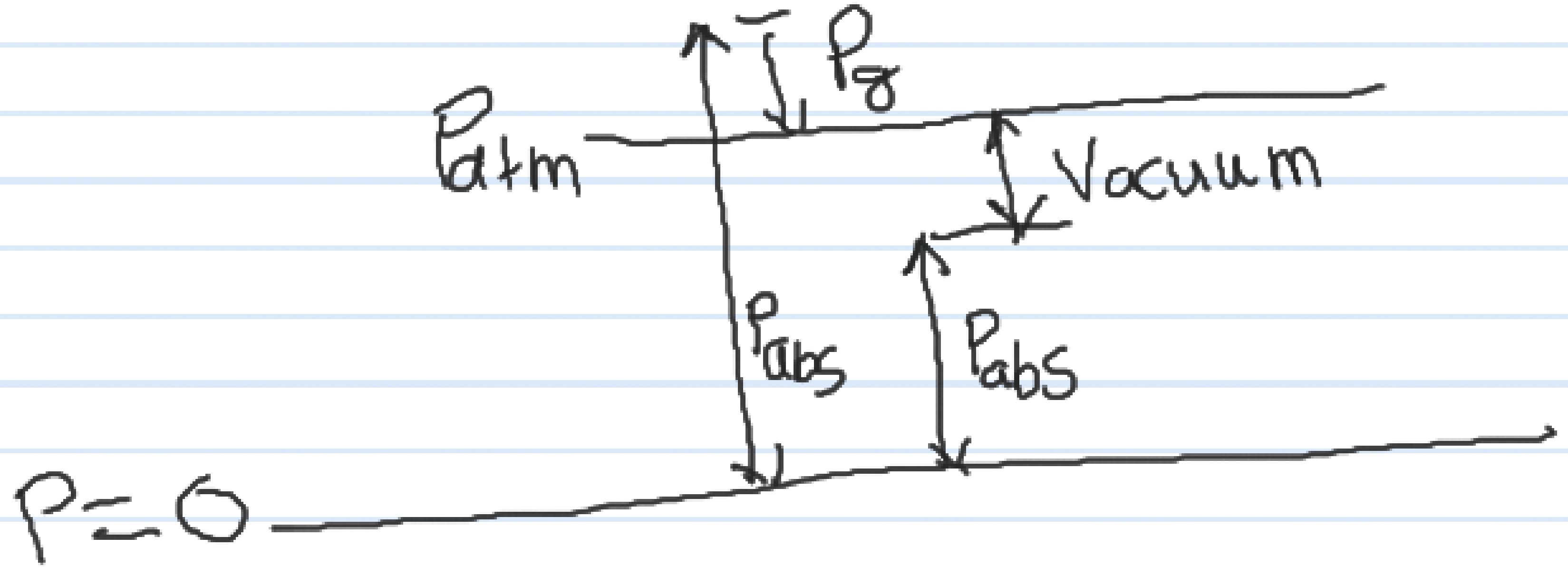
gauge pressure $P_g = P_{abs} - P_{atm}$

vacuum : $P_{atm} - P_{abs}$

Pressure units: N/m^2 (pascal Pa), atm, psi, kg_f/cm^2, bar, mmHg

$1\ atm = 1.01325\ bar = 1.01325 \times 10^5\ Pa = 14.7\ psi$

$= 1.033\ kg_f/cm^2 = 760\ mmHg$



$1\ kg_f = 9.81\ N$

psi = pound force/in^2

Question: convert

$1\ kg_f/cm^2 = ?\ Pa$

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Conversion of units and equations

Units: To convert one unit to another, just substitute the equivalent values of unit in other system

Ex: 7 Hougan and watson text: $k = 16.2 \frac{Btu \cdot F}{s\,ft} = 0.067 \frac{kcal}{s.m}$

→ Numerical value of constant depends on units.

Equation: To convert an equation containing dimensional constant, substitute equivalent values in desired units: Ex.8 and Ex-9 (Hougan & Watson)

An equation must be dimensionally consistent i.e. it must have equal dimensions of units in both side of equality sign '='. For examble; $P = A - \frac{B}{T+C}$ [Antoine eq.]

P = pressure (Pa), T = temperature (°C)
A = constant (Pa)
C = constant (°C)
B = constant (Pa·°C)

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Equations
- Dimensional equations ⇒ have same dimensions of units in both sides of '='
- Dimensionless equation ⇒ have no net dimension. If any constant exists it is also unitless and independent of units used.

Example: $Nu = 0.023 Re^{0.8} Pr^{0.33}$

We Nu = Nusselt no. $= \frac{hD}{k}$ where h = heat transfer coeff. D = length, k = thermal conductivity

Re = Reynold's no. $= \frac{Dv\rho}{\mu}$ where D = diameter, v = velocity, ρ = density, μ = viscosity

Pr = Prandtl no. $= \frac{C_p \mu}{k}$ where C_p = heat capacity, μ = viscosity, k = thermal conductivity

Problem: Given rate expression as $r_A = 0.005 C_A^2$, where $r_A = \frac{mol}{cm^3 \cdot min}$, $C_A = \frac{mol}{m^3}$

Find rate expression if $r_A = \frac{mol}{L \cdot hr}$ and $C_A = \frac{mol}{L}$

Problems and Solutions: Conversion of Unit and Equations

(1) [A] Convert heat capacity expression $C_p = a + bT$ into $C_p' = a' + b'T'$ where

$$C_p = \frac{cal}{(mol)(K)},\ T = K,\ C_p' = \frac{Jule}{(mol)(C^o)},\ T' = {}^oC$$

Solution:-

$$C_p \frac{cal}{(mol)(K)} = C_p' \frac{Jule}{(mol)(C^o)} = C_p' \frac{(1/4.18)\,cal}{(mol)(K)} = \frac{0.239\,C_p'\,cal}{(mol)(K)}$$

therefore $C_p' = \frac{C_p}{0.239} = 4.18\,C_p$

$$T\,K = T'\,{}^oC = T'\,K,$$

therefore $T = T'$

Substituting C_p and T in terms of C_p' and T' in given eq. $C_p = a + bT$

$$0.239\,C_p' = a + bT'$$

or $C_p' = \frac{a}{0.239} + \frac{b}{0.238} T' = 4.18a + 4.18bT' = a' + b'T'$

where $a' = 4.18a$ and $b' = 4.18b$

Thus $C_p' = 4.18(a + bT')$ Answer

1(B) What are the units of a and b?

Solution :- since quantities with same units can be added OR subtracted

unit of a = unit of bT = unit of $(a+bT)$ = unit of C_p = $\frac{cal}{(mol)(K)}$

unit of b = $\frac{\text{unit of } C_p}{\text{unit of } T}$ = $\frac{cal}{(mol)(K^2)}$