



## Note PHY 2 - Formulas

Physics 2 (Trường Đại học Quốc tế, Đại học Quốc gia Thành phố Hồ Chí Minh)

# PHYSICS 2

## Fluid mechanics:

Density:  $\rho = \frac{m}{V}$

Pressure:  $p = \frac{F}{A}$

Pressure: at some point:

$$p = p_0 + \rho gh$$

↑                    ↑                    ↘  
absolute    atmospheric    gauge

Pascal's principle:

$$\Delta p = \frac{F_i}{A_i} = \frac{F_o}{A_o}$$

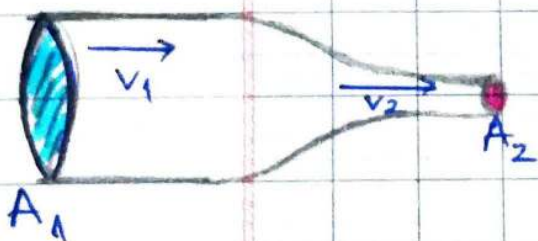
A: area

Archimedes' principle:  
(buoyant force)

$$F_b = \rho_{\text{fluid}} \cdot g \cdot V_{\text{obj}}$$

The equation of continuity

$$A_1 v_1 = A_2 v_2$$

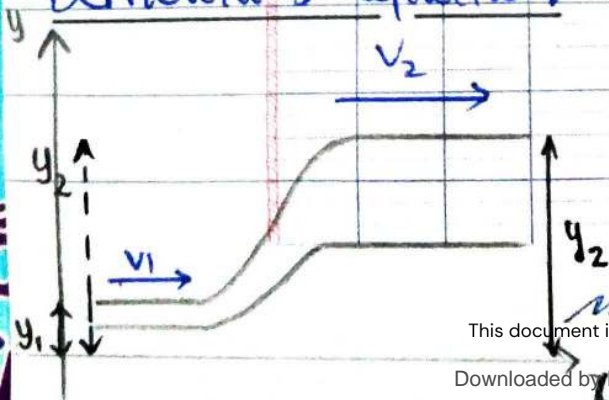


Volume flow rate:  $R = Av$

Mass flow rate:  $R_m = \rho Av$

Bernoulli's equation

$$p_1 + \frac{1}{2} \rho_1 v_1^2 + \rho_1 g y_1 = \text{constant}$$





# Heat, Temperature & 1<sup>st</sup> Law of THERMODYNAMICS:

thermal contact ; thermal equilibrium : trao đổi nhiệt.

Conversion

$$T_K = T_C + 273.15$$

$$T_F = \frac{9}{5} T_C + 32$$



$$\begin{cases} T_x = C_{P_x} \\ T_h = C_{P_h} \end{cases} \Rightarrow \frac{T_x}{P_x} = \frac{T_h}{P_h}$$

Thermal expansion:

$$\begin{aligned} \text{Linear} &: \Delta L = L \alpha \Delta T \\ \text{Area} &: \Delta A = A \alpha_A \Delta T \\ \text{Volume} &: \Delta V = V \beta \Delta T \end{aligned}$$

$$\alpha = \frac{1}{2} \alpha_A = \frac{1}{3} \beta$$

Heat capacity:

$$Q = C \cdot \Delta T \quad (J/K)$$

Specific heat:

$$Q = mc \Delta T = mc (T_f - T_i)$$

cal/gC or J/kgK

Phase change:

liquid  $\rightarrow$  gas : vaporization  
solid  $\rightarrow$  liquid : fusion

$$Q = Lm$$

(J/kg)

Work and Heat in Thermodynamic Process

$$W = p \Delta V \longrightarrow W = \int p dV$$

Net work done

$$\begin{cases} \Delta V > 0 \text{ (expand)} \rightarrow W > 0 \\ \Delta V < 0 \text{ (compressed)} \rightarrow W < 0 \end{cases} \quad \begin{aligned} &\text{clockwise: } W_{\text{net}} > 0 \\ &\text{counter-cw: } W_{\text{net}} < 0 \end{aligned}$$

Một trang vở một tương lai



# The 1<sup>st</sup> Law of Thermodynamics

$$\Delta E_{\text{int}} = E_{\text{intf}} - E_{\text{inti}} = Q - W$$

does not depend on the path, just states

$$W: \text{work done by the gas} = -W_{\text{on}}: \text{work done on the system}$$

Adiabatic:  $Q = 0 \Rightarrow \Delta E = -W$

Constant-volume:  $W = 0 \Rightarrow \Delta E = Q$

Cyclical processes:  $\Delta E_{\text{net}} = 0 \Rightarrow Q = W$

Free expansion:  $Q = W = 0$

$$W_{\text{net}} = \sum W$$

$$Q_{\text{net}} = \sum Q$$

$$\Delta E_{\text{net}} = Q_{\text{net}} - W_{\text{net}}$$

## Heat Transfer Mechanisms:

Conduction rate:  $P_{\text{cond}} = KA \frac{T_H - T_C}{L} = \frac{Q}{t}$

Resistance:

$$R = \frac{L}{K}$$

material  $\Rightarrow$  thermal conductivity | good conductors = high  $K$  = low  $R$

n materials: 
$$P_{\text{cond}} = \frac{A(T_H - T_C)}{\sum_{i=1}^n \left( \frac{L_i}{K_i} \right)}$$

Radiation rate:  $P_{\text{rad}} = \sigma \cdot \epsilon \cdot A \cdot T^4$

Stefan Boltzman constant

emissivity

$$\sigma = 5.6703 \times 10^{-8} \text{ W/m}^2\text{K}^4$$



# physics 2

## CHAPTER 3: IDEAL GASES (I.G.)

1 mole =  $N_A = 6.02 \times 10^{23}$  units (atoms molecules)  
↑  
Avogadro's number

Number of moles :  $n = \frac{N}{N_A}$  ← number of units (atoms or molecules)  
mass of sample

$$n = \frac{M_{\text{sample}}}{M} = \frac{M_{\text{sample}}}{m N_A}$$

↑ molar mass (g/mole)      ↑ mass of molecule.

### EXPERIMENTAL LAWS & the EQUATION OF STATE.

Boyle's Law : For a given mass, at constant (Boyle-Mariotte) temperature (isothermal), the pressure  $pV = \text{const}$  times the volume is a constant for I.G.

Charles's Law : For a given mass, at constant temp.  $V = \text{const} \times T$  (isobaric), the volume is directly proportional to the temperature.

Gay-Lussac's Law : For a given mass, at constant volume (isochoric), the pressure is directly proportional to the temperature.

Ideal Gas Law.

$$pV = nRT$$

(Pa)(m<sup>3</sup>) (mol) (K).

2

$$pV = NKT$$

↑ number of units  
(Pa)(m<sup>3</sup>) (K) (K)

$$R = 8.31 \text{ J/K.mol} = 0.082 \dots$$

$K$ : Boltzmann constant

$$K = R/N_A = 1.38 \times 10^{-23} \text{ J/K}$$



WORK DONE BY AN IDEAL GAS at CONSTANT TEMP.

$$W = \int_{V_i}^{V_f} p \cdot dV$$

ISOCHORIC :  $W = 0$   
 $V = \text{const}$

ISOBARIC  $W = p \Delta V$   
 $p = \text{const}$   
 $= p(V_f - V_i)$

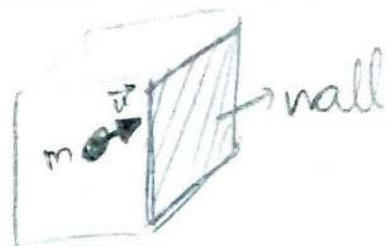
ISOTHERMAL  $W = nRT \cdot \ln \frac{V_f}{V_i}$   
 $T = \text{const}$

$$\star W = nRT \cdot \ln \frac{V_f}{V_i} = NKT \cdot \ln \frac{V_f}{V_i}$$

249 13 14 16 17 / 30 =

## MOLECULAR MODEL for an IDEAL GAS.

Pressure, Temperature & RMS speed.



$$p = \frac{nM v_{rms}^2}{3V}$$

OR

$$v_{rms} = \sqrt{\frac{3RT}{M}} \quad (M = \text{molar mass})$$

$8.31 \text{ J/molK}$   
 $\text{kg/mol} \rightarrow \times 10^{-3}$

$$pV = nRT = p \cdot \frac{m}{\rho} = nRT = p \cdot \frac{nM}{\rho} = n \cdot RT \Rightarrow \frac{RT}{M} = \frac{p}{\rho} \Rightarrow v_{rms} = \sqrt{\frac{3p}{\rho}}$$

$$v_{rms} = \sqrt{\frac{3p}{\rho}}$$

density

Average speed:

$$\bar{v}^2 = \frac{8RT}{\pi M}$$

Most probable speed

$$v_p = \sqrt{\frac{2RT}{M}}$$

Translational Kinetic Energy

Boltzman :  $1.38 \times 10^{-23} \text{ J/K}$

$$\bar{K} = \frac{1}{2} m \bar{v}^2 = \frac{1}{2} m v_{rms}^2 \Rightarrow$$

$$\bar{K} = \frac{3}{2} \cdot \frac{RT}{N_A} = \frac{3}{2} kT$$

independent of molar mass

18 20 23 24 27

Mean free path:  $\lambda = \frac{1}{\pi d^2 \frac{N}{V}}$  (units)

$$\lambda = \frac{1}{\sqrt{2} \pi d^2 \frac{N}{V}} = \frac{KT}{\sqrt{2} \pi d^2 p}$$

$\star$  New pressure: TORRICELLI

$$1 \text{ torr} = 1316 \times 10^{-6} \text{ atm} = 133 \text{ Pa}$$

- All are moving: (in atoms)

- Average time between collisions:

$$t = \frac{\lambda}{v} = \frac{1}{\sqrt{2} \pi d^2 \frac{N}{V} v}$$

- Frequency:  $f = \frac{1}{t}$

$$f = \sqrt{2} \pi d^2 \frac{p}{KT} v$$

★ Only for monatomic gas:

Internal energy:  $\Delta E_{\text{int}} = \frac{3}{2} n R \Delta T$

molar specific heat:  $Q = C n \Delta T$   
heat capacity ( $\text{J/mol}\cdot\text{K}$ )

$$\Delta E_{\text{int}} = Q - W$$

• Molar specific heat at constant volume (isochoric)

$$C_V = \frac{3}{2} R = 12.5 \text{ J/mol}\cdot\text{K}$$

$$\rightarrow \Delta E_{\text{int}} = \frac{3}{2} n R \Delta T = n C_V \Delta T$$

$$E_{\text{int}} = n C_V T$$

$$8.31 \text{ J/mol}\cdot\text{K}$$

• Molar specific heat at constant pressure (isobaric)

$$C_P = C_V + R = \frac{5}{2} R \text{ (J/mol}\cdot\text{K)}$$

$$\Delta E_{\text{int}} = Q - W = n C_V \Delta T$$

• isothermal:  $\Rightarrow \Delta E_{\text{int}} = 0 \Rightarrow Q = W$

★ The Equipartition-of-Energy Theorem:

degrees of freedom:  $\left\{ \begin{array}{l} \text{translational (của 1 ngiệm)} \\ \text{rotational (của } n \text{ ngiệm)} \end{array} \right.$

$\rightarrow$  total of trans & rota. =  $f$

$$\Delta E_{\text{int}} = \left(\frac{f}{2}\right) n R \Delta T$$

$$C_V = \left(\frac{f}{2}\right) R$$

$$C_P = C_V + R = \left(\frac{f+2}{2}\right) R$$

Monatomic:  $f = 3$

Diatomic:  $f = 5$

Polyatomic:  $f = 6$



## The Adiabatic Expansion of an ideal gases:

$$Q = 0 \rightarrow$$

$$pV^\gamma = \text{constant}$$

$$TV^{\gamma-1} = \text{constant}$$

$$\gamma = \frac{C_p}{C_v}$$

$$\gamma = \frac{f+2}{f}$$

Free expansion

$$\rightarrow Q = W = 0 \rightarrow \Delta E_{\text{int}} = 0 \rightarrow T_i = T_f$$

$$pV^\gamma = \text{constant} \Rightarrow p_i V_i = p_f V_f$$

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# CHAPTER 4 ENTROPY & the 2<sup>nd</sup> Law of THERMODYNAMICS

$\Delta S$ : heat/energy per degree Kelvin temperature.

## Reversible vs. Irreversible process:

- |  |   |
|--|---|
| <ul style="list-style-type: none"> <li>- can be reversed</li> <li>- causes no change in system &amp; surroundings</li> </ul> | <ul style="list-style-type: none"> <li>- cannot return to initial state (both system &amp; surroundings)</li> </ul> |
|--|---|

Change in Entropy:  $\Delta S = S_f - S_i = \int_i^f \frac{dQ}{T}$

for irreversible process:  $\Delta S > 0$ . for reversible process:  $\Delta S < 0$

if <u>T is constant</u> : $\Delta S = \frac{Q}{T}$	adiabatic process: $\Delta S = 0$
$\Delta S = \frac{Q}{T} = \frac{W}{T} = nR \ln \frac{V_f}{V_i}$	if <u>V is constant</u> : $\Delta S = nC_v \ln \frac{T_f}{T_i}$

Entropy as a state function:  $\Delta S = nR \ln \frac{V_f}{V_i} + nC_v \ln \frac{T_f}{T_i}$

$\frac{dE_{int}}{nCdT} = dQ - \underbrace{pdV}_{pdV}$

Entropy of phase change:

$\Delta S = \frac{L_m}{T}$

entropy only depend on initial & final

13 7 10 14 15 18 / 556

## The 2<sup>nd</sup> Law of THERMODYNAMICS

$\Delta S \geq 0$

If a process occurs in a closed system, the entropy of the system increases for irreversible processes & remains constant for reversible processes. It never decreases.



Carnot Engine 2 adiabatic + 2 isothermal + closed cycle.

↳ absorbs  $|Q_H|$  at  $T_H$  & discharges  $|Q_L|$  at  $T_L$

- closed cycle:  $\Delta E_{int} = 0 \rightarrow W = |Q_H| - |Q_L|$

work done by the engine  $\rightarrow$  net energy absorbed by engine

- The change in entropy:  $\Delta S = \Delta S_H + \Delta S_L$

closed cycle:  $\frac{|Q_H|}{T_H} = \frac{|Q_L|}{T_L}$

$$= \frac{|Q_H|}{T_H} - \frac{|Q_L|}{T_L}$$

- Efficiency:  $\epsilon = \frac{\text{energy we get}}{\text{energy we pay for}} = \frac{W}{|Q_H|}$

$$\epsilon_{\text{Carnot}} = \frac{W}{|Q_H|} = 1 - \frac{|Q_L|}{|Q_H|}$$

Perfect engine:

$$\epsilon_c = 1; Q_L = 0$$

Refrigerators:

- Efficiency:  $K = \frac{\text{What we want}}{\text{what we pay for}} = \frac{|Q_L|}{|W|}$

for a Carnot fridge:

$$|W| = |Q_H| - |Q_L|$$

$$K_c = \frac{|Q_L|}{|Q_H| - |Q_L|} = \frac{T_L}{T_H - T_L}$$

$\rightarrow$  no perfect refrigerators. ( $|Q_H| = |Q_L|$ ).

- The efficiencies of real Engine

$$\epsilon_x < \epsilon_c$$

engine.

Carnot



## Statistical View of Entropy

- $N = n_1 + n_2$  : total molecules in an isolated box.
- $(n_1, n_2)$  : a configuration.

Multiplicity (number of microstates).

$$W = \frac{N!}{n_1! n_2!}$$

★ Boltzmann's entropy equation :

$$S = k \cdot \ln W$$

$1.38 \times 10^{-23} \text{ J/K}$  (pointing to  $k$ )  
multiplicity (pointing to  $W$ )