Physics 2

Chapter 1: Fluid Mechanics

1. Density and Pressure

Density

$$\rho = \frac{m}{V} \qquad (\text{kg/m}^3)$$

Pressure

$$p = \frac{F}{A} \qquad (\text{Pa})$$

2. Fluids at Rest

Pressure of fluid at height h (absolute pressure)

$$p = p_0 + \rho g h \qquad (\text{Pa})$$

*(Tính áp suất dựa trên độ cao của cột chất lỏng, **xuống cộng, lên trừ**)*

Gauge pressure

$$p_G = p - p_0 = \rho g h \qquad (\text{Pa})$$

Pascal's principle

$$\frac{F_1}{A_1} = \frac{F_2}{A_2} \text{ or } F_1 s_1 = F_2 s_2$$

Archimedes' Principle (Buoyant force)

$$F_b = \rho_{\text{fluid}} g V_{\text{submerged}} \qquad (\text{N})$$

3. Moving Fluid

Equation of continuity

$$A_1 v_1 = A_2 v_2$$

Volume flow rate

$$R_v = Av \qquad (\text{m}^3/\text{s})$$

Mass flow rate

$$R_m = \rho R_v = \rho A v \qquad (\text{kg/s})$$

Bernoulli's equation

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

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Chapter 2: Heat, Temperature and the Zero-th Law of Thermodynamics

1. Thermal expansion

Coefficient of Linear expansion (Hệ số giãn nở tuyến tính): α ($°C^{-1}$ or K^{-1})

Linear expansion

$$L = L_0(1 + \alpha\Delta T) \leftrightarrow \Delta L = L_0\alpha\Delta T \qquad (m)$$

Area expansion ($\alpha_A = 2\alpha$)

$$A = A_0(1 + \alpha_A\Delta T) \leftrightarrow \Delta A = A_0\alpha_A\Delta T \qquad (m^2)$$

Volume expansion ($\beta = 3\alpha$)

$$V = V_0(1 + \beta\Delta T) \leftrightarrow \Delta V = V_0\beta\Delta T \qquad (m^3)$$

2. Heat

Heat transfer

$$Q = mc\Delta T \qquad (J)$$

Phase change

$$Q = Lm \qquad (J)$$

Thermal equilibrium equation

$$\sum Q = 0 \leftrightarrow Q_1 + Q_2 + Q_3 + \cdots = 0$$

3. Heat Transfer Mechanisms

Assume that heat is transferred form high temperature side T_H (°C or K) to low temperature side T_L (°C or K) by uniform rod of length L (m) cross sectional area A (m^2) with thermal conductivity k ($W \cdot m^{-1}K^{-1}$), the **conduction power** is given by

$$P_{\text{cond}} = \frac{Q}{\Delta t} = kA\frac{T_H - T_L}{L} \qquad (W)$$

For a compound slab containing several materials of thicknesses $L_1, L_2, \ldots$ and thermal conductivities $k_1, k_2, \ldots$ the **conduction power** becomes

$$P_{\text{cond}} = A\frac{T_H - T_L}{\sum L_i/k_i} \qquad (W)$$

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Chapter 3: Heat, Work and the First Law of Thermodynamics

1. First Law of Thermodynamics

$$\Delta E_{int} = Q - W \qquad \text{(J)}$$

Note that:

- For a closed cycle $\Delta E_{int} = 0$, $W > 0$ if gas goes clockwise direction and vice versa.
- Gas which goes following positive direction of V-axis leads to $W > 0$ and vice versa.
- Heat $Q < 0$ if it releases and $Q > 0$ if it absorbs.

2. Work

$$W = \int_{V_i}^{V_f} p\, dV \qquad \text{(J)}$$

(Nếu đồ thị biểu diễn quá trình biến đổi của chất khi mà tạo thành vòng kín cùng chiều kim đồng hồ thì $W_{\text{net}} > 0$, ngược chiều $W_{\text{net}} < 0$)

Isobaric ($p = \text{const}$)

$$W = p\Delta V \qquad \text{(J)}$$

Isochoric ($V = \text{const}$)

$$W = 0 \qquad \text{(J)}$$

Isothermal ($T = \text{const}$)

$$W = nRT \ln \frac{V_f}{V_i} \qquad \text{(J)}$$

Adiabatic ($Q = 0$)

$$W = -\Delta E_{int} \qquad \text{(J)}$$

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Chapter 4: The Kinetic Theory of Gases

1. Ideal Gas

Ideal gas equation

$$pV = nRT \leftrightarrow pV = NkT$$

Where:

- p, V, T: pressure (Pa), volume (m^3), temperature (K) of the gas, respectively.
- n: number of moles of the gas.
- N: number of molecules of the gas
- $R = 8.31 \text{ J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$: universal gas constant .
- $k = 1.38 \times 10^{-23} \text{ m}^2 \cdot \text{kg} \cdot \text{s}^{-2} \cdot \text{K}^{-1}$: Boltzmann constant.
- $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$: Avogadro constant.

(Số phân tử trong 1 mol chất khí)

This equation leads to $nR = Nk$

2. Kinetic Theory of Gases

Assuming that the ideal gas is a monatomic gas (individual atom as Ar, Ne, He)
The mean free path for a gas molecule

$$\lambda = \frac{1}{\pi\sqrt{2}d^2 N/V} \tag{m}$$

(Khoảng cách trung bình giữa các nguyên tử)

Root-mean-square speed

$$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3kT}{m_{\text{atom}}}} = \sqrt{\frac{3p}{\rho}} \tag{m/s}$$

Average speed

$$v_{ave} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8kT}{\pi m_{\text{atom}}}} = \sqrt{\frac{8p}{\pi\rho}} \tag{m/s}$$

Most probable speed

$$v_{mp} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2kT}{m_{\text{atom}}}} = \sqrt{\frac{2p}{\rho}} \tag{m/s}$$

The mean free time (average time between collisions)

$$t_{\text{mean}} = \frac{\lambda}{v} \tag{s}$$

(Thời gian trung bình giữa các lần va chạm)

Average translational kinetic energy

$$\overline{K} = \frac{3}{2}nRT = \frac{3}{2}NkT \tag{J}$$

(Động năng trung bình của một chất khí ở nhiệt độ T, nếu xét 1 nguyên tử thì N = 1, nếu xét 1 mol thì n = 1)

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3. Molar Specific Heats of an Ideal Gas

Classifying the ideal gases into three types:

- Monatomic: $f = 3$.
- Diatomic: $f = 5$.
- Polyatomic: $f = 7$.

Isochoric ($V = $ const)

$$C_v = \frac{f}{2} R$$

Isobaric ($p = $ const)

$$C_p = C_v + R = \frac{f + 2}{2} R$$

4. Sate Conversion of an Ideal Gas

$$\frac{p_i V_i}{T_i} = \frac{p_f V_f}{T_f}$$

Isobaric ($p = $ const)

$$\frac{V_i}{T_i} = \frac{V_f}{T_f}$$

Isochoric ($V = $ const)

$$\frac{p_i}{T_i} = \frac{p_f}{T_f}$$

Isothermal ($T = $ const)

$$p_i V_i = p_f V_f$$

Adiabatic ($Q = 0$)

$$\gamma = \frac{C_p}{C_v} = \frac{f + 2}{f}$$
$$p_i V_i^{\gamma} = p_f V_f^{\gamma}$$
$$T_i V_i^{\gamma - 1} = T_f V_f^{\gamma - 1}$$

5. Heat and First law of Thermodynamics

First law of Thermodynamics

$$\Delta E_{int} = Q - W = n C_v \Delta T \qquad (\text{J})$$

Heat

$$Q = n C \Delta T \qquad (\text{J})$$

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6. Summary

Process	State Conversion	Work	Heat
Common	$\dfrac{p_i V_i}{T_i} = \dfrac{p_f V_f}{T_f}$	$\Delta E_{int} = Q - W = nC_v \Delta T$	
Isobaric ($p = $ const)	$\dfrac{V_i}{T_i} = \dfrac{V_f}{T_f}$	$W = p\Delta V$	$Q = nC_p \Delta T$
Isochoric ($V = $ const)	$\dfrac{p_i}{T_i} = \dfrac{p_f}{T_f}$	$W = 0$	$Q = nC_v \Delta T$
Isothermal ($T = $ const)	$p_i V_i = p_f V_f$	$W = nRT \ln \dfrac{V_f}{V_i}$	$Q = W$
Adiabatic ($Q = 0$)	$p_i V_i^{\gamma} = p_f V_f^{\gamma}$ $T_i V_i^{\gamma-1} = T_f V_f^{\gamma-1}$	$W = -\Delta E_{int}$	$Q = 0$

Isobaric ($p = $ const)

$$p\Delta V = nR\Delta T$$

Isochoric ($V = $ const)

$$V\Delta p = nR\Delta T$$

For a particular process

$$\Delta(pV) = nR\Delta T \leftrightarrow p_f V_f - p_i V_i = nR\Delta T$$

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Chapter 5: Entropy and the Second Law of Thermodynamics

1. Change in Entropy

$$\Delta S = \int_i^f \frac{dQ}{T} \qquad (\text{J/K})$$

2. Second Law of Thermodynamics

The Second Law of Thermodynamics states that the change in entropy of an isolated system always non negative, and for a system with all processes are reversible the change in entropy equals to zero.

$$\Delta S \geq 0$$

3. Entropy in Ideal gas

$$\Delta S = S_f - S_i = nR \ln \frac{V_f}{V_i} + nC_v \ln \frac{T_f}{T_i} \qquad (\text{J/K})$$

Isobaric ($p = \text{const}$)

$$\Delta S = nC_p \ln \frac{T_f}{T_i} \qquad (\text{J/K})$$

Isochoric ($V = \text{const}$)

$$\Delta S = nC_v \ln \frac{T_f}{T_i} \qquad (\text{J/K})$$

Isothermal ($T = \text{const}$)

$$\Delta S = nR \ln \frac{V_f}{V_i} = \frac{Q}{T} = \frac{W}{T} \qquad (\text{J/K})$$

Adiabatic ($Q = 0$)

$$\Delta S = 0 \qquad (\text{J/K})$$

4. Entropy in Liquid and Solid

Cooling or heating

$$\Delta S = mc \ln \frac{T_f}{T_i} \qquad (\text{J/K})$$

Phase change

$$\Delta S = \frac{Lm}{T} \qquad (\text{J/K})$$

Un-changing temperature process

$$\Delta S = \frac{Q}{T} \qquad (\text{J/K})$$