

The quality of a saturated liquid is ?

$$x = 0$$

Ex2 Energy Balance

a) A fan uses 30W of electric power to discharge air at a rate of $1.5 \frac{\text{kg}}{\text{s}}$. What is the speed of the discharged air?

Draw diagram

$$\dot{E}_{\text{in}} - \dot{E}_{\text{out}} = \frac{dE_{\text{sys}}}{dt} = 0$$

$$\dot{Q}_{\text{in}} - \dot{Q}_{\text{out}} + \dot{W}_{\text{in}} - \dot{W}_{\text{out}} + \dot{E}_{\text{mass,in}} - \dot{E}_{\text{mass,out}} = 0$$

$$0 - 0 + 30 - 0 + m_{\text{in}} \frac{V_{\text{in}}^2}{2} - m_{\text{out}} \frac{V_{\text{out}}^2}{2} = 0$$

$$m_{\text{in}} = m_{\text{out}}, V_{\text{in}} = 0$$

$$30 - 1.5 \left(\frac{V^2}{2} \right) = 0$$

$$30 = 0.75 V^2$$

$$\boxed{V = 6.32 \text{ m/s}}$$

$$\dot{E}_{\text{mass}} = m \frac{V^2}{2} = \frac{1}{2} E$$

b) Now suppose you have a classroom with 30 people in it, each generating 4000 kJ/hr of heat. Heat is also leaving the room at a rate of ~~3000~~ 15 W/s . How many fans (like above) blowing air out of the classroom would be needed to maintain a constant temperature in the room?

Draw diagram

$$\dot{Q}_{\text{in}} - \dot{Q}_{\text{out}} + \dot{W}_{\text{in}} - \dot{W}_{\text{out}} + \dot{E}_{\text{mass,in}} - \dot{E}_{\text{mass,out}} = 0$$

$$30(4000 \frac{\text{kJ}}{\text{hr}}) \left(\frac{1000}{3600} \right) - 3000 \text{ W} + 0 - 0 - (1.5 \frac{\text{kg}}{\text{s}}) \left(\frac{6.32^2}{2} \right) (x) = 0$$

$$3333.3 \text{ W} - 3000 \text{ W} - 30x = 0$$

$$30x = 333.3 \text{ W}$$

$$x = 11.1 \rightarrow \boxed{12 \text{ fans}}$$

Ideal Gases

- for ideal gas: U , h , C_p , C_v , are all functions of T

$$\Delta U = \int_1^2 C_v(T) dT = \overline{C_v} (T_2 - T_1)$$

evaluated at $\frac{T_1 + T_2}{2}$

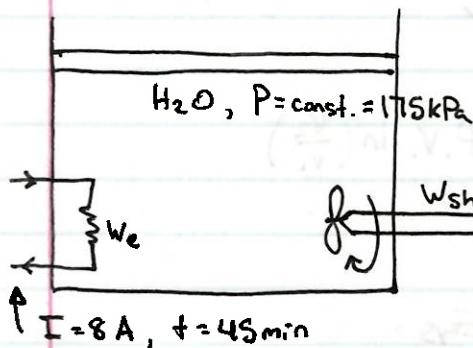
$$\Delta h = \int_1^2 C_p(T) dT = \overline{C_p} (T_2 - T_1)$$

- Relations:

$$R = C_p - C_v$$

$$k = \gamma = \frac{C_p}{C_v} \approx 1.4 \text{ air}$$

Problem 4-34



- $V_1 = 5 \text{ L}$ of saturated liquid water
- If half of the liquid is evaporated, determine the voltage of the source

$$W_{sh} = 400 \text{ kJ} \quad E_{in} - E_{out} = \Delta E_{sys}$$

$$-(W_b + W_{other}) = \Delta U$$

$$-(W_{b,out} - W_e - W_{sh}) = \Delta U$$

$$W_e + W_{sh} = \Delta U + W_b = \Delta H$$

$$IV\Delta t + 400 \text{ kJ} = m(h_2 - h_1)$$

- From Table A-8:

$$h_1 = h_f @ 175 \text{ kPa} = 487.01 \text{ kJ/kg}$$

$$V_1 = v_f = 0.001057 \text{ m}^3/\text{kg}$$

$$h_2 = h_f + x h_{fg} = 487.01 + (1/2)(2213.1) = 1593.6 \text{ kJ/kg}$$

$$m = \frac{V_1}{V_1} = \frac{0.005 \text{ m}^3}{0.001057 \text{ m}^3/\text{kg}} = 4.731 \text{ kg}$$

- Plug in:

$$V(8)(45 \times 60) + 400 \text{ kJ} = (4.731 \text{ kg})(1593.6 - 487.01) \text{ kJ/kg}$$

$\hookrightarrow V = 223.9 \text{ V}$

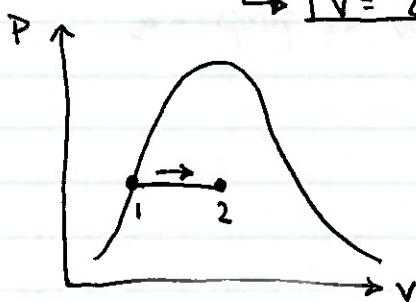
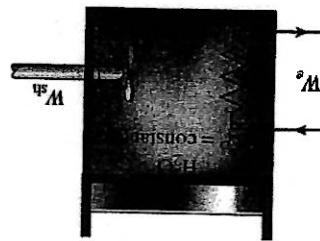


FIGURE P4-81



4-81 Air is contained in a cylinder device fitted with a piston-cylinder. The piston initially rests on a set of stops, and a pressure of 300 kPa is required to move the piston. Initially, the air is at 100 kPa and 27°C and occupies a volume of 0.1 m³. Determine the amount of heat transferred to the air, in kJ, while increasing the temperature to 1200 K. Assume air has constant specific heats evaluated at 300 K. Answer: 340 J

FIGURE P4-38



4-38 An installed piston-cylinder device contains 5 L of saturated liquid water at a constant pressure of 175 kPa. Water is stirred by a paddle wheel while a current of 8 A flows for 45 min through a resistor placed in the water. If one-half of the liquid is evaporated during this constant-pressure process and the paddle-wheel work amounts to 400 J, determine the voltage of the source. Also, show the process on a $P-V$ -diagram with respect to saturation lines. Answer: 224 V

4-67 Consider a piston-cylinder device that contains nitrogen gas as the system. Initially, the system is at 1 MPa and 427°C. It now undergoes an isobaric process until its temperature is 27°C. Determine the final pressure and the heat transferred, in kJ/kg, associated with this process. Answer: 416 kJ/kg

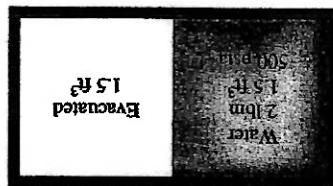
4-14 A mass of 2.4 kg of air at 150 kPa and 120°C is contained in a gas-tight, frictionless piston-cylinder device. The air is now compressed to a final pressure of 600 kPa. During the process, heat is transferred from the air such that the temperature inside the cylinder remains constant. Calculate the work input during this process. Answer: 272 kJ

H.W. #3

3-78 A 1-m³ tank containing air at 25°C and 500 kPa is connected through a valve to another tank containing 5 kg of air at 35°C and 200 kPa. Now the valve is opened, and the entire system is allowed to reach thermal equilibrium with the surroundings, which are at 20°C. Determine the volume of the second tank and the final equilibrium pressure of air.

Answers: 2.21 m³, 284.1 kPa

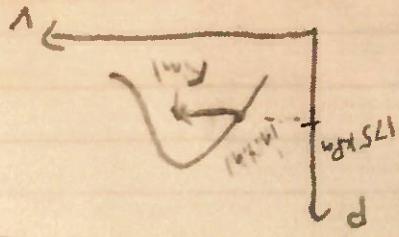
FIGURE P3-34E



3-81 2-lbm of water at 500 psia initially fill the 1.5-ft³ left chamber of a partitioned system. The right chamber's volume is also 1.5 ft³, and it is initially evacuated. The partition is shown ruptured, and heat is transferred to the water until its temperature is 300°F. Determine the final pressure of water, in psia, and the total internal energy, in Btu, at the final state.

Condition	description	<i>P</i> , kPa	<i>T</i> , °C	<i>V</i> , m ³ /kg	<i>h</i> , kJ/kg	<i>h</i> , kJ/kg (if applicable)
200	130	2706.3				
400	3277.0					
800	30					
450	147.90					

3-28 If sufficient data are provided, complete the blank cells in the following table of properties of water. In the last column describe the condition of water as compressed liquid, saturated mixture, superheated vapor, or unsaturated mixture, and, if applicable, give the quality.



$$V = 223.81$$

$$4834000 = 2160 V$$

$$5234415 = (V_{0.14m^2})(8A)(45m) \cdot \frac{1}{(0.25)} + 400$$

$$W_{0.14m^2} = (V_{0.14m^2})(45m) \Delta t$$

$$\Delta H = 4.73(1514 - 4870) = 5234415$$

$$\text{as } h_{\text{final}} = 1594 \text{ kJ} ; \Delta H = m(h_{\text{final}} - h_{\text{initial}})$$

$$= (1122)(0.1 + 0.5) = 14870 = h_{\text{initial}} + X(h_f) = h_{\text{initial}}$$

$$\text{from } \frac{\Delta H}{x} = \frac{V}{2.5} = 0.5 \text{ or } 50\% \text{ drop in pressure}$$

$$\text{from } \frac{\Delta H}{x} : m = \frac{\text{Volume}}{\text{Specific Volume}} = \frac{5 \cdot 10^{-3}}{0.001057} = 4.73 \text{ kg}$$

$$h_f = 2213.1 \text{ kJ/kg} \quad V_r = 0.001057 \text{ m}^3$$

$$\textcircled{a} \quad 175 \text{ kPa} + \text{able A-5} \quad h_f = 487.01 \text{ kJ/kg}$$

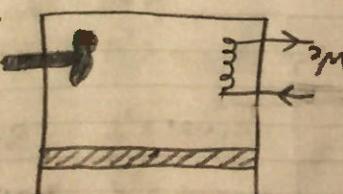
$\frac{1}{2} \text{ work done by water} \text{ when } w = 400 \text{ kJ} \quad \text{Find } V \text{ and } P-V$

$$w = 450 \text{ m}$$

$$C = 84$$

$$P = 175 \text{ kPa}$$

5L water



enthalpy

$$Q = H \nabla - \nabla H - W_{\text{external}} + W_{\text{paddle}} \leftarrow Q = E_A - E_i \rightarrow E_A - E_i = Q$$

$$U_{\text{Final}} = 919.78 \text{ kPa}$$

$$\frac{459.89 \text{ kPa}}{160} \cdot 216 = 919.78$$

$$0.2293 = \frac{830.25}{U_{\text{Final}} - 269.51} \quad \text{So } 190.39 = U_{\text{Final}} - 269.51$$

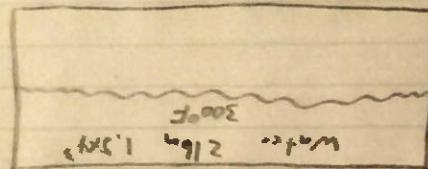
$$X = \frac{u_s}{U_{\text{Final}} - u_s} \quad @ 300^\circ F \quad u_s = 269.51 \frac{160}{160} \quad u_s = 830.25 \frac{160}{160}$$

$$X = \frac{V_{\text{Final}} - V_e}{V_s} = \frac{1.5 - 0.01745}{6.4463} = 0.2293$$

$$P = 67.028 \frac{160}{160} \quad V_s = 0.01745 \frac{160}{160} \quad V_e = 6.4463 \quad @ 300^\circ F$$

$$10212 \text{ m}^3 \text{ air} / 216 \text{ m}^3 \text{ water} = 54.7 \text{ kg/m}^3 \text{ mass density}$$

$$\frac{m}{V} = \frac{6000 \frac{160}{160}}{1.5 \frac{160}{160}} = 1.5 \frac{160}{160} \quad \text{Surface volume (a) = } \frac{1.5 \frac{160}{160}}{1.2 \frac{160}{160}} = 1.2 \frac{160}{160}$$



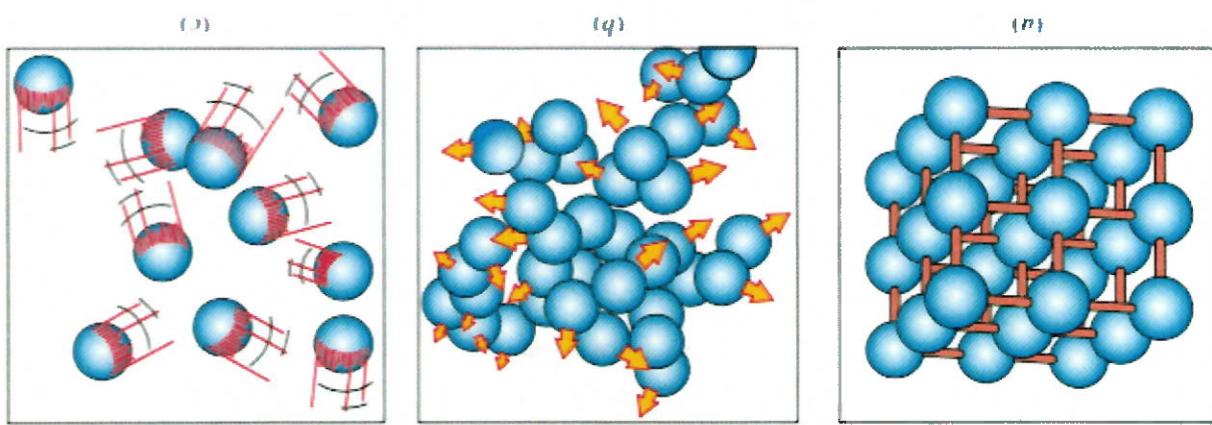
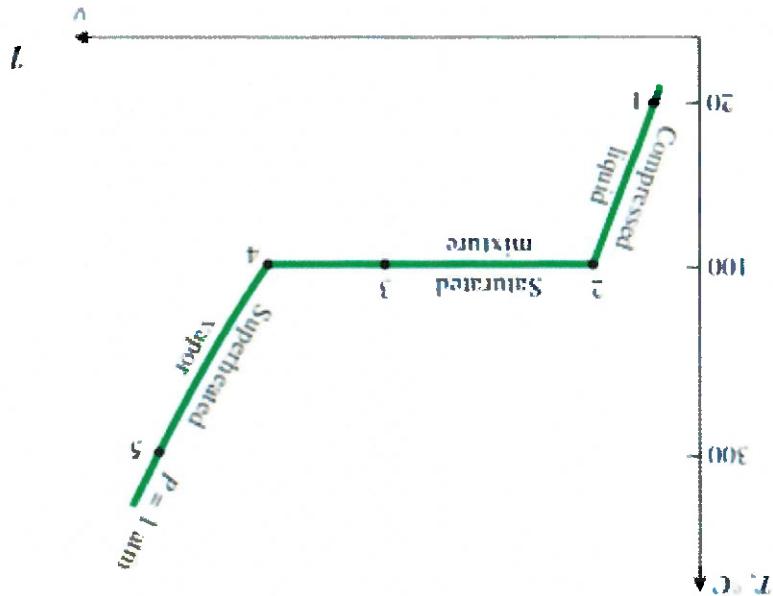
Final

Emph	1.5kg/m³	500kg/m³
Water	216m	

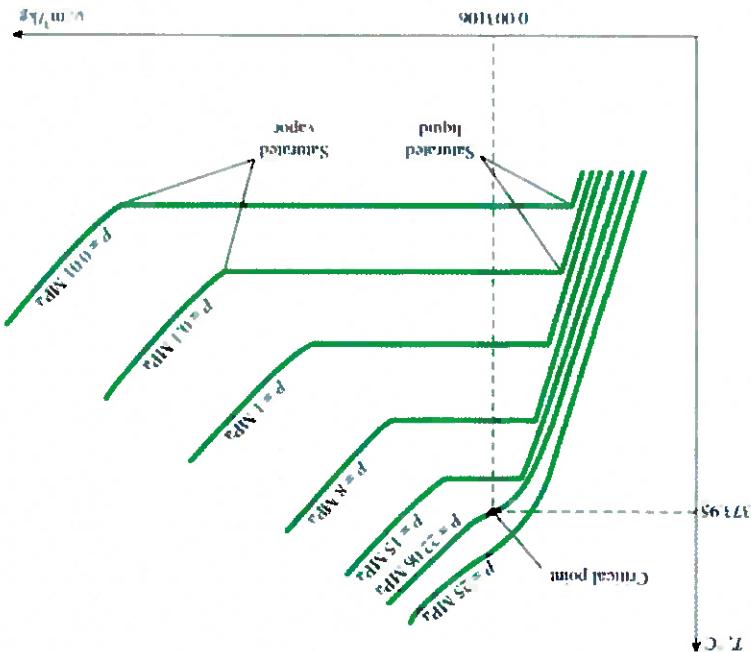
Total

Final	3413	216m Water	300°F	Final P & U Final
Initial: 1.5kg/m³ 648 Pa	216m Water	500 kg/m³		

Saturated vapor - vapor that is about to condense
 Constant temperature during phase change \rightarrow heat of formation
 Saturated liquid - liquid that is about to vaporize
 compressed liquid, or a subcooled liquid, meaning that it is not about to vaporize.



e.g. air
 - Does not have to be only one element; can be a mixture as long as it is homogeneous
 Pure substance - fixed chemical composition throughout



Lower pressure to flash freeze

Liquid nitrogen exposed to atmosphere to keep things at a constant temperatures

Liquid vaporizing -> latent heat of vaporization

Solid melting -> latent heat of fusion

At a given pressure, the temperature at which a pure substance changes phase is called the saturation pressure P_{sat} . Likewise, at a given temperature, the pressure at which a pure substance changes temperature T_{sat} . Likewise, at a given temperature T , the pressure at which a pure substance changes phase is called the saturation pressure P_{sat} .

Superheated vapor - vapor that is not about to condense

$$R = \frac{M}{R_n}$$

$$PV = RT$$

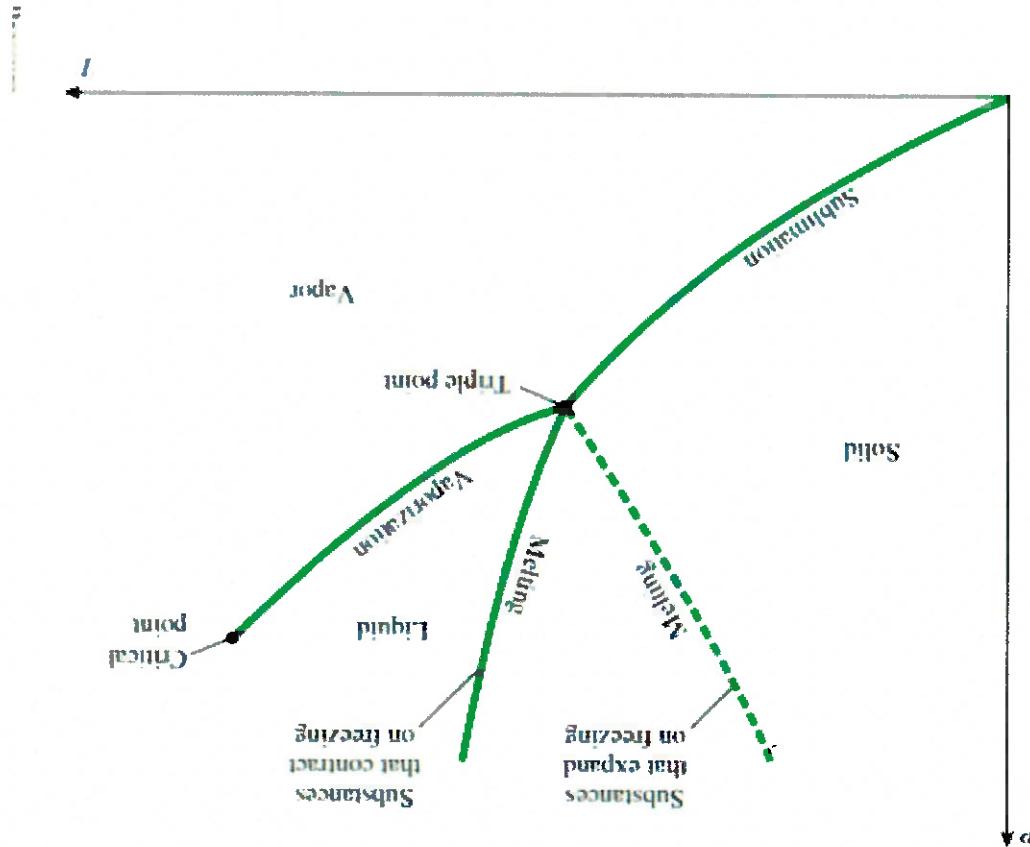
Treat compressed liquid like saturated liquid at same temperature

$$\delta(\Delta V + \beta C) = \delta\sigma X$$

$$X = \text{quality} = m_{\text{vapo}}/m_{\text{total}}$$

H_f for enthalpy of vaporization

$$h = u + pV \quad (\text{J/Kg})$$



reduced pressure and T^* , the reduced temperature.

$$\frac{T^*}{T} = \frac{p^*}{p} \quad \text{and} \quad T^* = \frac{p^*}{p} T \quad (3-20)$$

$$P_v = ZRT$$

$$Z = \frac{RT}{P_v}$$

compressibility factor Z defined as

In the range of practical interest, many familiar gases such as air, nitrogen, oxygen, hydrogen, helium, argon, neon, krypton, and even heavier gases such as carbon dioxide can be treated as ideal gases with negligible error (often less than 1 percent). Dense gases such as water vapor in steam power plants and refrigerant vapor in refrigerators, however, should not be treated as ideal gases. Instead, the property tables should be used for these substances.

$$C_p dT = dh$$

$$C_V dT = du$$

$$C_p = \frac{dh}{dT} \quad C_V = \frac{du}{dT}$$

C_p, C_V are properties
Relation to other properties:

$$\text{Const. Pressure} \leftarrow C_p \quad \text{Const. } C_V \leftarrow C_V$$

$$\text{Const. Volume} \leftarrow C_V \quad \text{Const. } C_p \leftarrow C_p$$

Energy required to raise temp. ΔT

Specific Heats

for const. pressure process: $\Delta U + W_b = \Delta H$

$$\Delta H = (W_b + W_{other}) = \Delta U$$

$$\Delta U_{in} - W_{out, in} = \Delta U + \Delta K.E + \Delta P.E$$

Convolution: $\Delta_{in} = \text{positive}, W_{out} = \text{positive}$ * for adiabatic, $\Delta E_{sys} = 0$

$$\Delta_{in} - E_{out} = \Delta E_{sys} \quad \text{OR} \quad E_{in} - E_{out} = \Delta E_{sys}$$

Energy Balance

$$\int_1^2 P dV = \int_1^2 \frac{V}{RT} dV = \frac{1}{R} \int_1^2 \frac{dV}{V} = R T \ln\left(\frac{V_2}{V_1}\right) = P \cdot V_1 \ln\left(\frac{V_2}{V_1}\right)$$

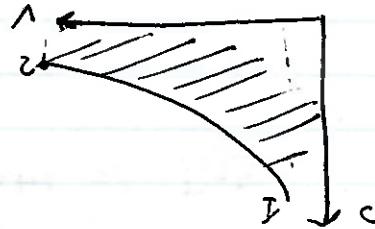
for a const. temp process:

$$\int_1^2 P dV = P(V_2 - V_1) = P(V_2 - V_1)$$

for a const. volume process:

$$W_b = 0$$

for a const. pressure process:



$$W_b = \int_1^2 P dV \leftarrow \text{Area under PV diagram}$$

If we have a moving boundary (like a piston):

Boundary Work

$$P_i = 91.9 \text{ kPa}$$

$$P_i = 90 \text{ kPa} + 0.2943 \text{ kPa} + 1.5696 \text{ kPa}$$

$$+ (800 \text{ kg/m}^3)(9.81 \text{ N/kg})(20 \text{ cm}) \left(\frac{1000 \text{ N/m}^2}{1 \text{ kPa}} \right)$$

$$(3 \text{ m}) \left(\frac{1000 \text{ N/m}^2}{1 \text{ kPa}} \right)$$

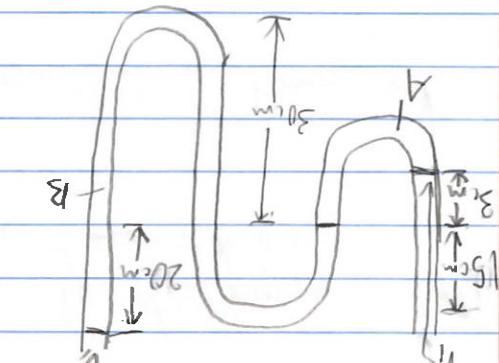
$$h_B = 15 \text{ cm}$$

$$h_A = 5 \text{ cm}$$

$$P_i = P_{atm} + \rho_A g h_A + \rho_B g h_B$$

$$h_B < h_A \rightarrow P_i < P_{atm}$$

$$P_i > P_{atm}$$



Ex 1 Measure the CL-Tq) P_{atm}

$$\rho_B = 800 \text{ kg/m}^3$$

$$\rho_A = 1000 \text{ kg/m}^3$$

$$P_{atm} = 90 \text{ kPa}$$