IIT Mandi

ME 104 **Engineering Thermodynamics**

Quiz – 1 **Total Marks: 30** **Time: 50 min**

Steam tables / property tables without any hand written material are allowed.

Instructions:

1. Clearly mention the assumptions made.
2. Draw system and system boundary wherever necessary. Draw p-v or T-v diagrams wherever necessary.
3. Assume any missing data.
4. Give answers as precisely as possible. Do not write irrelevant answers

Objective questions 14 x ½ =7

Encircle your answers.

1. The work done in compressing a gas isothermally is given by

   a. $\frac{\gamma}{\gamma-1}P_1V_1\left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma}{\gamma-1}}-1\right]$ b. $mRT_1 \ln (P_2/P_1)$ c. $mc_p(T_2-T_1)$ d. $mRT_1\left(1-\frac{T_2}{T_1}\right)$

2. Which one of the following statement is correct?
   a. Compressibility factor is unity for ideal gases
   b. Compressibility factor is zero for ideal gases
   c. Compressibility factor is lesser than unity for ideal gases
   d. Compressibility factor is more than unity for ideal gases

3. Which one of the following is correct about: the specific volume of water when heated from 0 °C
   a. first increases and then decreases c. increases steadily
   b. first decreases and then increases d. decreases steadily

4. Work transfer between the system and surroundings
   a. is a point function c. is a function of pressure only
   b. is always given by $\int pdv$ d. depends on the path followed by the system

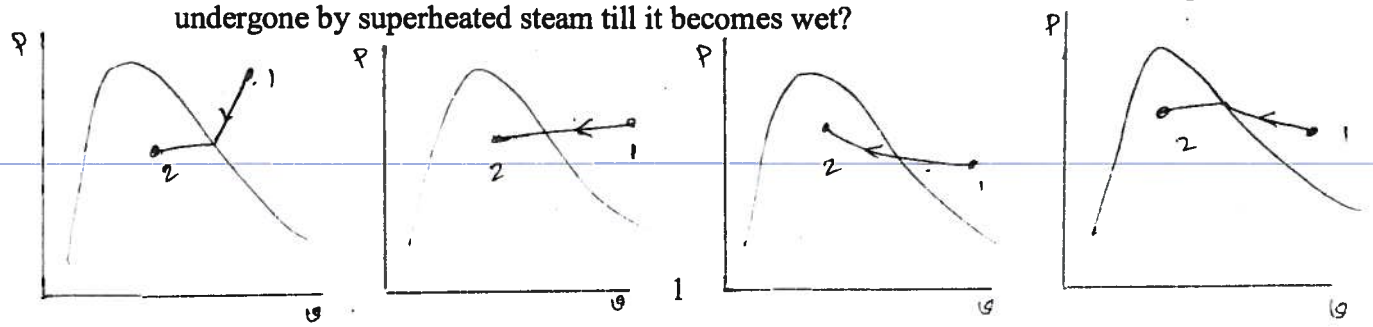
5. Which one of the following represents open thermodynamic system?
   a. manual ice cream freezer b. centrifugal pump c. pressure cooker d. bomb calorimeter

6. The ratio of two specific heats of air is equal to
   a. 0.17 b. 0.24 c. 0 714 d. 1.41

7. Work done is zero for the following process
   a. Constant volume b. free expansion c. both d. none

8. For which of the following substance, the gas laws can be used with minimum error
   a. Dry steam b. wet steam c. saturated steam d. super heated steam

9. Which one of the following p – v diagram for steam illustrates the isothermal process undergone by superheated steam till it becomes wet?



10. Polytropic index 'n' is given by

a. $\frac{\ln(p_2/p_1)}{\ln(v_1/v_2)}$ b. $\frac{\ln(p_1/p_2)}{\ln(v_1/v_2)}$ c. $\frac{\ln(v_1/v_2)}{\ln(p_2/p_1)}$ d. $\frac{\ln(v_2/v_1)}{\ln(p_2/p_1)}$

11. First law of thermodynamics was developed by
    a. Charles b. Joule C. Einstein d. Kelvin.
12. Water contained in a beaker can be made to boil by passing steam through it
    a. At atmospheric pressure
    b. At a pressure below the atmospheric pressure
    c. At a pressure greater than the atmospheric pressure
    d. Not possible
13. First law of thermodynamics defines
    a. work b. enthalpy c. internal energy d. heat
14. The process of sublimation is found to occur in the case of
    a. Liquid nitrogen b. Solid CO_2 c. solid O_2 d. air

3 x 1=3

15. Match the following

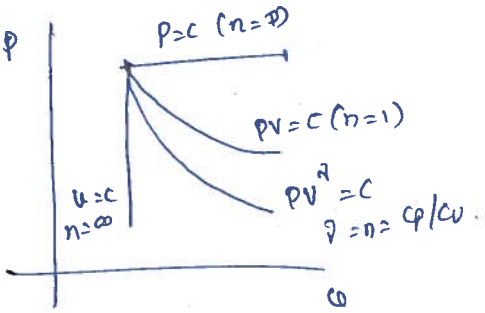
a. interchange of mass is not possible in	1. open system
b. Processes in which system returns to original condition	2. system
c. interchange of matter is possible in a	3.closed system
d. quantity of matter under consideration is	4. cycle

a – 3 b – 4 c – 1 d – 2

16. Match the following (index n in $pv^n=c$)

a.	adiabatic	1. infinite
b.	isothermal	2. $n=C_p/C_v$
c.	constant pressure	3. n=1
d.	consent volume	4. $n=(C_p-C_v)-1$
		5. n=0

a – 2 b – 3 c – 5 d – 1



17. match the following

a. Critical point	1. all 3 phases (solid, liq, vap) coexist in equilibrium
b. Sublimation	2. phase change from solid to liquid
c. Triple point	3. Properties of sat. liquid and vapour are identical
d. Melting	4. heating process where solid transforms to vapour directly

a – 3 b – 4 c – 1 d – 2

Answer the following questions in the space provided. 8 x 1 =8

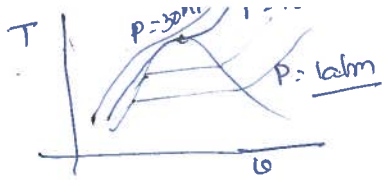
18. What is meant by thermodynamic equilibrium? What happens if a system is not in equilibrium?

A system that is in thermal, mechanical, chemical, phase ... eqm's is said to be in thermodynamic eqm. If the system is not in eqm., it tries to attain eqm.

Ex: If there are unbalanced forces, the pre. in system changes till mech. eqm is attained

19. You cooked food in a vessel with a tight lid. You kept the vessel in a refrigerator for some time and tried to open the lid after that. What experience you will get?

It becomes very difficult to open the lid, when we keep the vessel in refrigerator, the pre. of inside the vessel falls below atm (corresponding to Temp). ∴ There is suction from inside.



20. What is the difference between boiling of water at 1 atm (101.325 kPa) and 30 MPa?

At 1 atm, we have clear vaporization of phase change (water (l) → steam). We can see the different qualities. But at 30 MPa, ($P_{cr,water}$ = 22.09 MPa) we do not have any 2-phase region. Water continuously changes its sp. vol. & it is difficult to distinguish to separate liq & vap.

21. What is the state of air when a football is punctured? Why?

air coming out of foot ball is cooler (than atm.). when the air is coming out of football, the energy needed to come out of foot ball (boundary) is displaced by air ⇒ work done by system) is supplied by inside air ⇒ internal energy ↓. ⇒ Temp. falls.

22. Give two main differences between microscopic and macroscopic approaches.

	Microscopic	Macroscopic
i.	gives effects at molecular level.	Gives gross effects
ii.	Cannot be measured by instruments ex: Rotational energy of molecules.	can be measured by instruments Ex: P, T, ..

23. You have liquid fuel in the bottom portion of the container. Above this, you have air and fuel vapour. Do you call this system as pure substance? Why?

If the container is closed one, the system is not pure sub. Reason: composition is not same.

If we take only liq, the system is pure

If we take air + fuel vap, the system is not pure.

24. What is the physical significance of the compressibility factor Z?

it gives the deviation of the state of a substance from ideal gas behaviour.

The more the deviation from $Z = 1$, the more deviation from ideal gas behaviour.

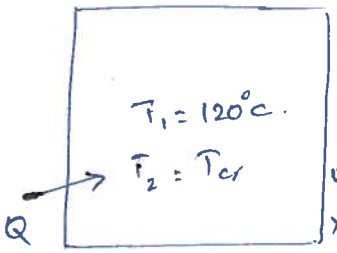
25. A fixed mass of an ideal gas is heated from 50 to 80°C at a constant pressure of (*a*) 1 atm and (*b*) 3 atm. For which case do you think the energy required will be greater? Why?

In both cases, energy needed is same. For an ideal gas, $C_p = f(T)$ only.

Pressure effect is negligible / zero not present.

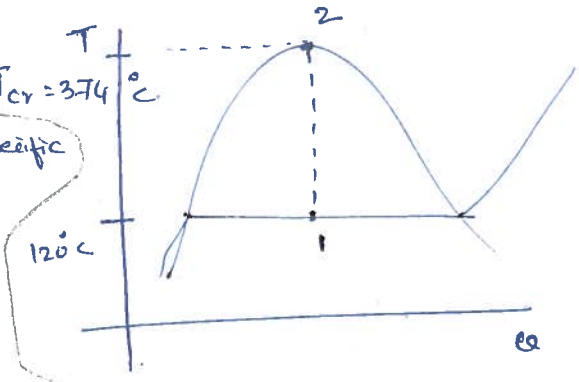
Answer the following questions using the appropriate tables / charts.

26. A rigid vessel contains saturated (liquid+vapor) water is at 120 °C. Heat is added to the vessel so that the final state passes through critical point. What should be the initial mass fraction of the liquid? 2



$P_1 = P_{sat}$ @ 120°C $P_2 = P_{cr}$

Given: we have a vessel with saturated water at 120°C. Its specific vol. ~~is such that~~, ~~its~~ at 120°C is equal to sp. vol. at the critical pt.



$\Rightarrow v_2 = v_1$ $v_2 = v$ @ T_{cr},

$v_2 = v_{@\,374.1°C} = 0.003155 = v_1$.

Find: initial mass fraction of liq = $1 - x$.

$v_1 = v_{f1} + x_1 v_{fg1} = 0.001060 + x_1 (0.89080 - 0.001060)$

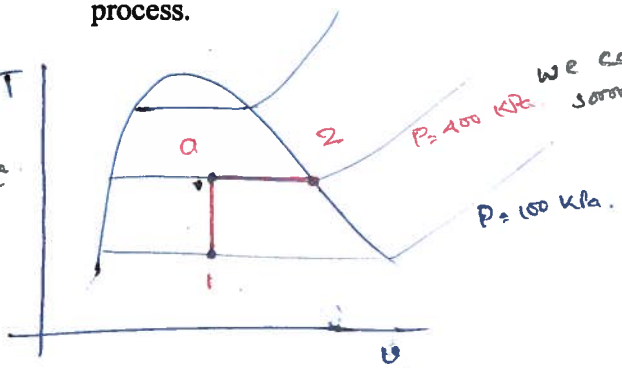
$= 0.003155$

$\Rightarrow x = 2.35 \times 10^{-3}$

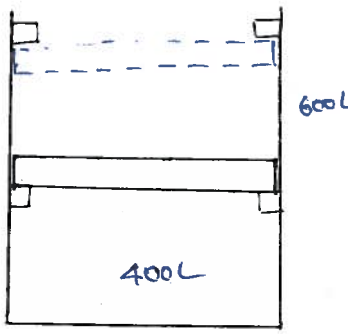
initial mass fraction of liq $= 1 - x = 0.9976$

27. Consider the piston/cylinder arrangement shown in Fig. A frictionless piston is free to move between two sets of stops. When the piston rests on the lower stops, the enclosed volume is 400 L. When the piston reaches the upper stops, the volume is 600 L. The cylinder initially contains water at 100 kPa, 20% quality. It is heated until the water eventually exists as saturated vapor. The mass of the piston requires 400 kPa pressure to move it against the outside ambient pressure. Determine the final pressure in the cylinder. Find whether the piston hits the upper stops or not. Determine the heat transfer and the work for the overall process. 7

This fig. should be drawn after finding the pressure



we can draw some rough fig.



Given: $V_{lower\ stops} = V_{1} = 400L$ $V_{upper\ stops} = 600L$ $P_1 = 100$ KPa, $x_1 = 0.2$, $P_{lift} = 400$ KPa.

Find: final pressure, whether piston hits the stops or not, work, heat transferred.

Sol:

The piston remains at lower stops till the pressure raises to 400 KPa. During this period, volume remains constant. As the piston starts moving, Pressure remains constant at volume

At state 1 (400L, 100 KPa, $x = 0.2$), $v_1 = v_{f1} + x_1 v_{fg1} = 0.001043 + 0.2(1.69296 - 0.001043)$

$= 0.34$ m³/kg.

mass of water $= \frac{V_1}{v_1} = \frac{0.4}{0.34} = 1.1765^{4}$ kg/

If the piston just starts lifting, $P = P_a = 400$ KPa. The specific volume (also mass & total vol.) is same as initial value (v_1) at this moment. We can find x_a

$v_a = v_1 = 0.34 = v_{fa} + x_a v_{fga} = 0.001084 + x_a(0.46138 - 0.001084)$

$\Rightarrow x_a = \dfrac{0.34 - 0.001084}{0.46138 - 0.001084} = 0.7363.$

$v_{fa} < v_a < v_{ga}$ we need to check it then it satisfies.

Now as we add heat, piston rises. We need to check whether the piston hits the stops or not.

i) If the pressure remains constant, & the water becomes saturated vapour.

$\Rightarrow P = 400$ KPa, $x = 1$. $\Rightarrow v_g = 0.46138$ m³/kg.

The volume of the cylinder corresponding to this sp. vol = mv

$= 1.1765 \times 0.46138$

$= 0.5428$ m³

$= 542.8$ L.

As this volume is less than the volume of the cyl. with piston at upper spots, the piston doesn't hit the stops.

$\therefore P = 400$ KPa. Correct figure comes after this.

ii) If the piston reached upper stops at $P = 400$ KPa, $v = \frac{V}{m} = \frac{0.6}{1.1765} = 0.51$ m³/kg.

at $P = 400$ KPa, $v = 0.51$ m³, water is in superheated state.

$\therefore$ Piston doesn't hit the upper stops.

iii) for $v_g = 0.51$ m³, $P_{sat} = 370$ KPa. As our pressure is > 370 KPa, it will not touch the upper stops.

work done $= \int P dV = \int_1^2 P dV + \int_a^2 P dV$ during 1-a: vol = c, $P_{sat} \uparrow$

$\Rightarrow dW = 0.$

$= \int_a^2 P dV = P(V_2 - V_a)$

$= 400(0.5428 - 0.4) = 57.12$ KJ.

From 1st law, we can write

$\delta Q = dU + \delta W + dKE + dPE$

Ass: Neglect changes in KE, PE.

In calculating internal energy, we don't need to bother about the intermediate states. We just need initial & final states as it is a property

$\Rightarrow \delta Q = dU + \delta W$ (or)

$Q = \Delta U + \delta W$

$= (3004.2 - 982.46) + 57.12$

$= 2078.9$ KJ

$u_1 = u_f + x u_{fg}$ |,

$= 417.33 + 0.2 \times 2088.7$

$= 835.074$ KJ/kg

$U_1 = m u_1 = 982.46$ KJ

$U_2 = m u_2 = 1.1765 \times 3557.55 = 3004.2$

28. A mass of 2 kg of benzene is in a 0.045 m^3 rigid container at a pressure of 3 MPa. Use the generalized compressibility charts to estimate the temperature. (T_{cr}=562.2 K, Pcr=4.89 MPa) 3

Given: $m = 2\,kg$. $V = 0.045\,m^3$. $P = 3\,MPa$. $T_{cr} = 562.2\,K$, $P_{cr} = 4.89\,MPa$.

Find: Temp. using generalised compressibility chart.

Assume mass of benzene

$\in C_6H_6 = 6\times12 + 6\times1 = 78$

$v = \frac{V}{m} = 0.0225\ m^3/kg$.

Pseudo sp. vol $= v_R = \frac{v}{R_a T_{cr}/P_{cr}} = \frac{0.0225}{\left(\frac{8.314}{78}\right)\times 562.2/4890}$

$= 1.83$.

$P_R = \frac{P}{P_{cr}} = \frac{3}{4.89} = 0.6135$.

From the graph, at $P_R = 0.61$ & $v_R = 1.83$, $T_R = 1.21$

$\Rightarrow T_R = \frac{T}{T_{cr}} \Rightarrow T = 1.21\times 562.2 = 680.26$.

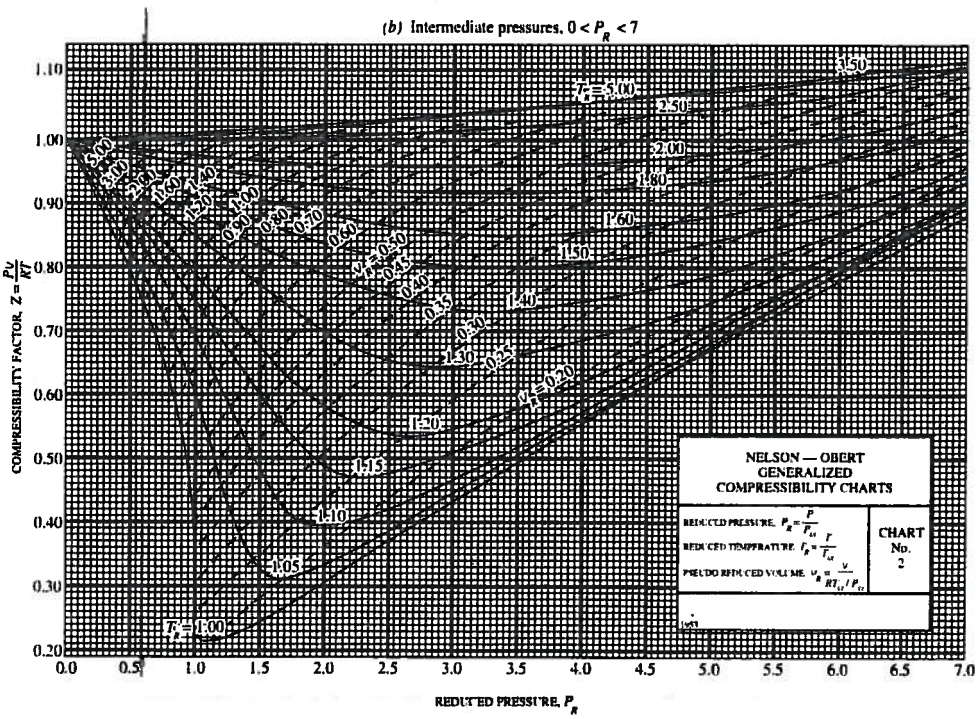


FIGURE A–15

Nelson–Obert generalized compressibility chart.

Used with permission of Dr. Edward E. Obert, University of Wisconsin.

Engineering Thermodynamics : Quiz - 1

(1) work done in compressing a gas $= \int P dV$

For isothermal case, $PV = C$. (or) $P_1V_1 = P_2V_2$

$\Rightarrow$ work $= \int_{P_1}^{P_2V_2} \frac{C}{V} dV = C \ln V\Big|_1^2 = P_1V_1 \ln \frac{V_2}{V_1} = mRT_1 \ln \frac{V_2}{V_1}$

$= mRT_2 \ln P_1/P_2$.

closed one is $\left(mRT_2 \ln P_2/P_1\right)$

(2) $Z = \frac{Pv}{RT}$. It gives the deviation of the substance from ideal gas. If the value is other than 1, then that substance is deviating from the ideal gas behav

$\therefore Z = 1$

(3) specific volume of water initially ↓ K then increase. ~~At 1 atm~~, This is the reason why ice floats on water a 0°C. water has max. density at 4°C

$\therefore$ water density increases till 4°C & then ↓ $\Rightarrow$ specific volume initially decreases & then increases after reaching the minimum.

(4) work done by system & ~~on~~ surr. depends on the paths followed by the sys.

Ex: If the system follows $P = C$, $W = \int P dV = P\Delta V$.

If the system follows polytropic process, $W = \frac{P_2V_2 - P_1V_1}{1-n}$.

(5) Centrifugal pump : The mass of liquid (pumps are for liquid) crosses the system (centrifugal pump) continuously.

All other systems (given) do not have continuous mass exchange. $\therefore$ They are not considered as open systems.

(6) $C_p = 1.005$ KJ/kg K $C_v = 0.718$ KJ/kg

ration : $C_p/C_v = 14$ $C_v/C_p \approx 0.714$.

(7) If we consider a closed system,

i) if there is no external work on the system, if only heat is added, work done is zero.

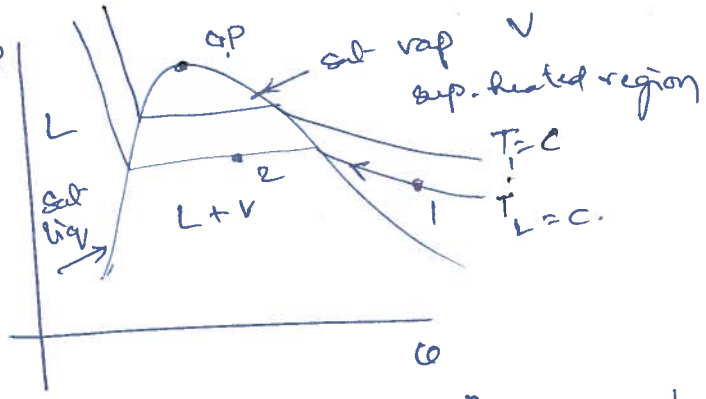
If there is ~~no~~ work ~~for~~ to the system, the work done $\neq 0$

→ In the free expansion of a gas (sys.), the work done is zero.

$\therefore$ a, b, c : any) is correct.

(8) In the case of superheated steam, the temp. of water is away from the sat. temp. at that pressure. As the gas laws can be applied with less error at high temp., gas laws can be used with min. error for superheated steam

(9)

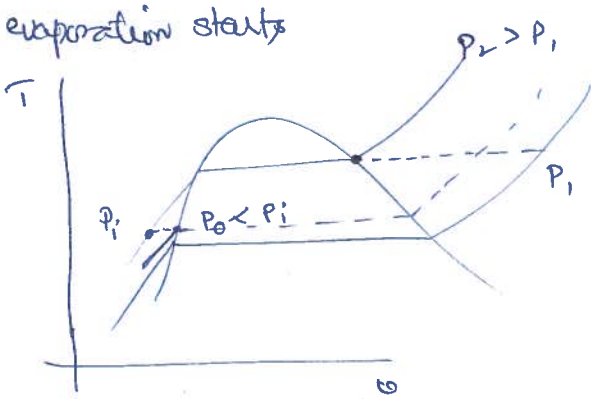


(10) $P_1 V_1^n = P_2 V_2^n \Rightarrow \left(\frac{P_1}{P_2}\right) = \left(\frac{V_2}{V_1}\right)^n \Rightarrow n \cdot \ln(V_2/V_1) = \ln(P_1/P_2)$

$\Rightarrow n = \frac{\ln(P_1/P_2)}{\ln(V_2/V_1)}$ (or) $n = \frac{\ln(P_2/P_1)}{\ln(V_1/V_2)}$

(11) Joule, from his expt.s he found that cyclic integral of heat is proportional to the cyclic integral of work.

(12) If we reduce the pressure of a substance, keeping the temp. constant, evaporation starts



If we send steam at lower pressure than atm.), the pressure inside the beaker is reduced & the water starts boiling at the same temp ($P = P_{sat.}@T$)

(13) First law defines enthalpy. We all know about heat, work, internal energy even before applying 1st law. With the help of 1st law, we defined $h = u + pv$.

(14) solid CO_2.