CLASS TEST

S.No : 02_SK_ME_ABCDEFGHI_25082025

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THERMODYNAMICS

MECHANICAL ENGINEERING

Date of Test : 25/08/2025

ANSWER KEY

1.	(b)	7.	(a)	13.	(a)	19.	(d)	25.	(a)
2.	(c)	8.	(a)	14.	(a)	20.	(c)	26.	(c)
3.	(b)	9.	(b)	15.	(a)	21.	(b)	27.	(c)
4.	(d)	10.	(d)	16.	(b)	22.	(a)	28.	(c)
5.	(b)	11.	(a)	17.	(c)	23.	(a)	29.	(d)
6.	(d)	12.	(c)	18.	(b)	24.	(a)	30.	(c)

DETAILED EXPLANATIONS

1. **(b)**

If temperature is lower than the saturation temperature corresponding to its pressure P, then the liquid phase of a pure substance is termed as sub-cooled liquid.

2. **(c)**

Number of phase, $P = 1 + 1 = 2$

Number of constituents, $C = 2$

From Gibbs phase rule,

$$\begin{aligned} P + F &= C + 2 \\ F &= C + 2 - P \\ F &= 2 + 2 - 2 \\ F &= 2 \end{aligned}$$

3. **(b)**

For the given process (3, 4)

$$\begin{aligned} \Delta U &= -650 \text{ (kJ)} \\ \Delta PE &= 0 \text{ (kJ)} \\ \Delta E &= -600 \text{ (kJ)} \end{aligned}$$

Change in total macroscopic energy (ΔE)

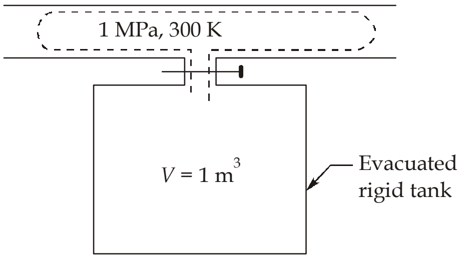
$$\begin{aligned} \Delta E &= \Delta U + \Delta KE + \Delta PE \\ -600 &= -650 + \Delta PE + 0 \\ \Delta KE &= (650 - 600) = 50 \text{ kJ} \end{aligned}$$

4. **(d)**

At the critical point the saturated liquid and saturated vapour states are identical.

So, $L_1 = L_2 = L_3$ (irrespective of working fluid)

5. **(b)**



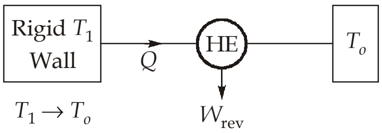
For this case the final temperature of air in the tank

$$\begin{aligned} T_{\text{final}} &= \gamma \cdot T_{\text{initial}} \\ T_{\text{final}} &= 1.4 \times 300 \text{ K} = 420 \text{ K} \end{aligned}$$

6. **(d)**

The efficiency of a reversible heat engine depends on the source and sink temperature.

7. **(a)**



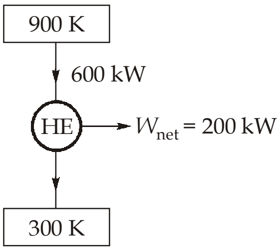
$$\int dW_{rev} = \int_{T_1}^{T_0}\left(1-\frac{T_o}{T}\right)(-mc_v dT)$$

$$W_{\text{rev}} = mc_v(T_1 - T_0) - mc_v T_o \ln\left(\frac{T_1}{T_0}\right)$$

For unit mass, $m = 1$ kg

$$W_{\text{rev}} = c_v\left[(T_1 - T_0) - T_0 \ln\left(\frac{T_1}{T_o}\right)\right]$$

9. **(b)**



$$W_{\text{reversible form}} = Q\left(1-\frac{T_L}{T_H}\right) = 600\left(1-\frac{300}{900}\right) = 400\text{ kW}$$

$$\text{Irreversibility} = W_{\text{rev}} - W_{\text{actual}}$$
$$= 400 - 200 = 200\text{ kW}$$

10. **(d)**

The process mentioned in the question is the case of free expansion. Since there is no restraining or opposing force or pressure as expansion occurs against vacuum. So work done is zero in case of free expansion process.

11. **(a)**

Cylinder volume, $V = 0.1\text{ m}^3$

Mole of propane (C_3H_8) = 100 mol

$P = 2$ MPa

The Van der Waals constant for propane

$a = 939.2\text{ kPa }(\text{m}^3/\text{kmol})^2$

$b = 0.0905\ (\text{m}^3/\text{kmol})$

$R_u = 8.3145$ J/mol K

From the Van der Waals equation

$$\left(P+\frac{a}{V^2}\right)(V-b) = \text{R.T.} \quad \text{...(i)}$$

$$\text{Molar volume, } V = \frac{0.1\text{ m}^3}{100\times10^{-3}\text{kmol}}$$

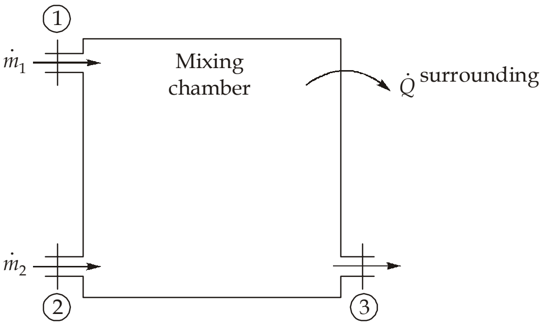
$$V = 1\text{ m}^3/\text{kmol}$$

From equation (i)

$$\left(2000+\frac{939.2}{1^2}\right)(1-0.0905) = 8.3145 \times T$$

$$T = 321.5\text{ K}$$

12. (c)



From steady flow energy equation (SFEE) by neglecting ΔKE and ΔPE

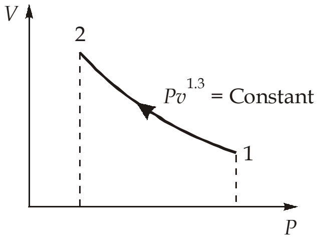
$$\dot{m}_1 h_1 + \dot{m}_2 h_2 - \dot{Q} = (\dot{m}_1 + \dot{m}_2)h_3 - \cancelto{0}{W_{net}}$$

$$\dot{m}_1 c_p T_1 + \dot{m}_2 c_p T_2 - \dot{Q} = (\dot{m}_1 + \dot{m}_2)c_p T_3$$

$$T_3 = \frac{\dot{m}_1 T_1 + \dot{m}_2 T_2}{\dot{m}_1 + \dot{m}_2} - \frac{\dot{Q}}{c_p(\dot{m}_1 + \dot{m}_2)}$$

13. (a)

Mass = 1 kg of ideal gas
Compressed $Pv^{1.3}$ = Constant
Initial, P_i = 100 kPa
T_i = 250 kPa
Final, T_f = 500 K
R = 287 J/kgK
γ = 1.4



$$W_{1\text{-}2} = -\left(\frac{P_2V_2 - P_1V_1}{n-1}\right)$$

$$= \frac{-mR(T_2 - T_1)}{n-1}$$

$$U_{1\text{-}2} = U_2 - U_1 = mc_v\,(T_2 - T_1)$$

$$Q_{1\text{-}2} = U_{1\text{-}2} + W_{1\text{-}2}$$

$$Q_{1\text{-}2} = 1\times 0.718(500-250) - \frac{1\times 0.287(500-250)}{1.3-1}$$

$$Q_{1\text{-}2} = -59.666 \text{ kJ}$$

$$Q_{1\text{-}2} = 59.666 \text{ kJ (Heat transfer from piston cylinder to its surrounding)}$$

Alternatively,

$$Q_{1\text{-}2} = \frac{\gamma - n}{\gamma - 1}\times\left(\frac{P_1V_1 - P_2V_2}{n-1}\right) = \frac{\gamma - n}{\gamma - 1}\times\frac{m\times R\times(T_1 - T_2)}{n-1}$$

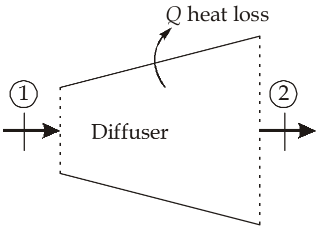
$$= \frac{1.4-1.3}{1.4-1}\times\frac{1\times 0.287\times(250-500)}{1.3-1}$$

$$Q_{1\text{-}2} = -59.666 \text{ kJ}$$

$$Q_{1\text{-}2} = 59.666 \text{ kJ (Heat transfer from piston cylinder to its surrounding)}$$

14. (a)

$\dot{m}_1 = 2$ kg/s,
$P_1 = 100$ kPa,
$T_1 = 273 + 30 = 303$ K;
$V_1 = 200$ m/s



$A_2 = 400 \times 10^{-4}$ m^2,
$T_2 = 273 + 45 = 318$ K,
$Q_{loss} = 4$ kW, $P_2 = ?$

Air, $\gamma = 1.4$

From steady flow energy equation,

$$h_1 + \frac{V_1^2}{2} + Q = h_2 + \frac{V_2^2}{2} + \overset{0}{\cancel{W}}_{net}$$

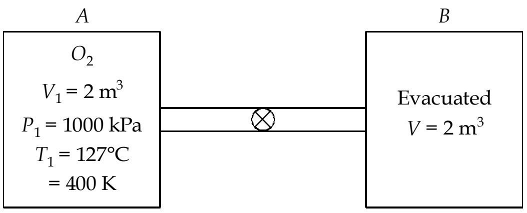
$$\left[1005(303-318) + \frac{200^2}{2}\right] - \frac{4000}{2} = \frac{V_2^2}{2}$$

$$\begin{aligned}
V_2 &= 43.0116 \text{ m/s} \\
\text{Mass flow rate} &= \rho_2 A_2 V_2 \\
2 &= \rho_2 \times 400 \times 10^{-4} \times 43.0116 \\
\rho_2 &= 1.1624 \text{ kg/m}^3 \\
P_2 &= \rho_2 R T_2 \\
&= 1.1624 \times 287 \times 318 = 106.094 \text{ kPa} \approx 106.1 \text{ kPa}
\end{aligned}$$

15. (a)

$$\begin{aligned}
v_{ideal} - v_{actual} &= 4.529 \times 10^{-3} \text{ m}^3/\text{kg} \\
z &= 0.84 \\
v_{com} - v_{actual} &= ? \\
v_{com} &= 0.84\, v_{ideal} \\
&= 0.84 \times \left(\frac{1 \times 0.0815 \times (273+50)}{1000}\right) = 0.022112 \text{ m}^3/\text{kg} \\
v_{ideal} &= 0.0263245 \text{ m}^3/\text{kg} \\
v_{actual} &= 0.0263245 - 4.529 \times 10^{-3} \\
&= 0.0217955 \text{ m}^3/\text{kg} \\
v_{com} - v_{actual} &= 0.022112 - 0.0217955 \\
v_{com} - v_{actual} &= 3.165 \times 10^{-4} \text{ m}^3/\text{kg} \\
v_{com} - v_{actual} &= 0.316 \times 10^{-3} \text{ m}^3/\text{kg}
\end{aligned}$$

16. (b)



Taking chamber A and chamber B together as a system.

$$dQ = dU + dW$$

Since $\quad dQ = dW = 0$

$\Rightarrow \quad dU = 0$

No change in internal energy ⇒ No change in temperature of air.

$$\text{Ideal gas equation}, T = \text{Constant}$$

$$\Rightarrow \quad P_1V_1 = P_2V_2$$

$$\Rightarrow \quad P_2 = \frac{P_1V_1}{V_2} = (1000)\times\frac{2}{4} = 500 \text{ kPa}$$

17. (c)

Mixture of gas,

$$\text{Oxygen } (O_2) = 0.1 \text{ kmol}$$

$$\text{Nitrogen } (N_2) = 0.1 \text{ kmol}$$

$$\text{Methane } (CH_4) = 0.8 \text{ kmol}$$

$$\text{Molar mass, } O_2 = 32 \text{ kg/kmol}$$

$$N_2 = 28 \text{ kg/kmol}$$

$$CH_4 = 16 \text{ kg/kmol}$$

$$\text{Mass of } O_2 = \text{Mole} \times \text{Molar mass}$$

$$= 0.1 \times 32 = 3.2 \text{ kg}$$

$$\text{Mass of } N_2 = \text{Mole} \times \text{Molar mass}$$

$$= 0.1 \times 28 = 2.8 \text{ kg}$$

$$\text{Mass of } CH_4 = \text{Mole} \times \text{Molar mass}$$

$$= 0.8 \times 16 = 12.8 \text{ kg}$$

$$\text{Mass fraction of } N_2 = \frac{m_{N_2}}{m_{O_2} + m_{N_2} + m_{CH_4}} = \left(\frac{2.8}{3.2 + 2.8 + 12.8}\right) = 0.148$$

18. (b)

From state postulate, $z = f(x, y)$

$$dz = \left(\frac{\partial z}{\partial x}\right)_y dx + \left(\frac{\partial z}{\partial y}\right)_x dy$$

Must satisfy, $\left(\frac{\partial z}{\partial x}\right)_y = \left(\frac{\partial z}{\partial y}\right)_x$

From, $dz = xdy + ydx$

$$\left(\frac{\partial z}{\partial x}\right)_y = 1$$

$$\left(\frac{\partial z}{\partial y}\right)_x = 1 \qquad \text{(Satisfied)}$$

From, $dz = xdy - ydx$

$$\left(\frac{\partial z}{\partial x}\right)_y = 1$$

$$\left(\frac{\partial z}{\partial y}\right)_x = -1 \qquad \text{(Not Satisfied)}$$

From $dz = 2dy + dx$

$$\left(\frac{\partial z}{\partial x}\right)_y = 0$$

$$\left(\frac{\partial z}{\partial y}\right)_x = 0 \qquad \text{(Satisfied)}$$

From
$$dz = \frac{dy}{x} - \frac{y}{x^2}dx$$

$$\left(\frac{\partial z}{\partial x}\right)_y = -\frac{1}{x^2}$$

$$\left(\frac{\partial z}{\partial y}\right)_x = -\frac{1}{x^2} \qquad \text{(Satisfied)}$$

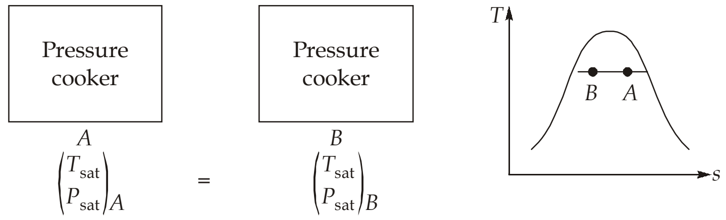
Hence, option (b) is correct.

19. **(d)**

From *Tds* relation, $dh = Tds + VdP$

For constant pressure, $\left(\frac{\partial h}{\partial s}\right)_P = T$

20. **(c)**



From Gibbs function,
$$g = h - Ts$$
$$dg = dh - Tds - sdT$$
$$dg = vdP - sdT$$
$$[(dg)_{PT}]_A = \left[\cancel{vdP}^0 - \cancel{sdT}^0\right]$$
$$(g)_{l,A} = (g)_{V,A}$$

Similarly,
$$[(dg)_{PT}]_B = \left[\cancel{vdP}^0 - \cancel{sdT}^0\right]$$
$$(g)_{l,B} = (g)_{v,B}$$

As the temperature and pressure are same for cooker A and B.
$$(g_l)_B = (g_v)_A$$

21. **(b)**

$$\log_e P_{sat} = A - \frac{B}{T} \qquad \text{... (i)}$$

From Clapeyron equation
$$\left(\frac{dP}{dT}\right)_{sat} = \frac{h_{fg}}{T.v_{fg}} = \frac{s_{fg}}{v_{fg}}$$

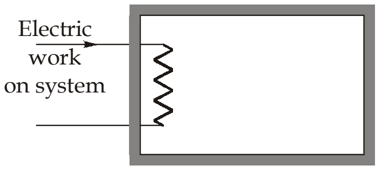
By differentiating equation (i) w.r.t. temperature (T),
$$\frac{1}{P_{sat}}\left(\frac{dP_{sat}}{dT}\right) = 0 - (-1 \times BT^{-2})$$

$$\left(\frac{dP_{sat}}{dT}\right) = \frac{B \cdot P_{sat}}{T^2} = \frac{s_{fg}}{v_{fg}}$$

$$s_{fg} = v_{fg}\frac{B \cdot P_{sat}}{T^2}$$

22. **(a)**

Insulated rigid tank,



Given: $v = 0.8\ \text{m}^3$, $m = 1.5$ kg, $P_i = 100$ kPa, $p_f = 135$ kPa, $T_o = 298$ K,

$PV = mRT$

At V = Constant

$$P \propto T$$

$$\frac{p_i}{p_f} = \frac{T_i}{T_f} \Rightarrow \frac{T_1}{T_2} = \frac{P_1}{P_2}$$

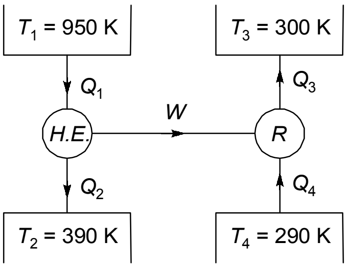
Exergy destroyed, $\Delta X = T_o S_{\text{gen}}$

$$\Delta X = 298 \times \left[mc_v \ln\left(\frac{T_2}{T_1}\right)\right] = 298 \times \left[1.5 \times 680 \ln\left(\frac{135}{100}\right)\right]$$

$$\Delta X = 91.219 \text{ kJ} \approx 91.2 \text{ kJ}$$

23. **(a)**

Work output from heat engine,



$$W = Q_1\left(1 - \frac{T_2}{T_1}\right)$$

$$W = Q_1\left(1 - \frac{390}{950}\right)$$

$$W = 0.589Q_1$$

For refrigerator work input, $W = Q_4\left(\frac{T_3}{T_4} - 1\right) = Q_4\left(\frac{300}{290} - 1\right)$

$$W = 0.034Q_4$$

$$\Rightarrow \quad 0.589Q_1 = 0.034Q_4$$

$$\Rightarrow \quad \frac{Q_4}{Q_1} = \frac{0.589}{0.034} = 17.32$$

24. **(a)**

P_o = 95 kPa
T_o = 27°C = 300 K
P_1 = 4 bar = 400 kPa
T_1 = 77°C = 350 K
P_2 = 1 bar = 100 kPa
T_2 = 37°C = 310 K

$$V_1 = \frac{mRT_1}{P_1} = \frac{1 \times 0.287 \times 350}{400} = 0.25 \text{ m}^3$$

$$V_2 = \frac{mRT_2}{P_2} = \frac{1 \times 0.287 \times 310}{100} = 0.89 \text{ m}^3$$

Work done on atmosphere, $W = P_o(V_2 - V_1)$ [Work done by the system on the surrounding]

$$= 95 \times (0.89 - 0.25) = 60.77 \text{ kJ}$$

25. **(a)**

Given:

$P_1 = 0.8725$ kPa, $T_1 = 273 + 5 = 278$ K, $P_2 = ?$, $T_2 = 10 + 273 = 283$ K, $R = 0.4615$ kJ/kgK, $h_{fg} = 2489.1$ kJ/kg

From Clapeyron equation,

$$\left(\frac{dP}{dT}\right)_{sat} = \frac{P.h_{fg}}{RT^2}$$

$$\left(\frac{dP}{P}\right) = \frac{h_{fg}}{R}\left(\frac{dT}{T^2}\right)$$

For small temperature internal,

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{h_{fg}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$\ln\left(\frac{P_2}{0.8725}\right) = \frac{2489.1}{0.4615}\left(\frac{1}{278} - \frac{1}{283}\right)$$

$$P_2 = 1.229 \text{ kPa} \approx 1.23 \text{ kPa}$$

26. **(c)**

$$\text{Exergy} = h_1 - h_2 - T_0(s_1 - s_2)$$

$$T_1 = 600\text{ K}$$

$$T_2 = T_o = 300\text{K}$$

$$P_1 = 200 \text{ kPa}$$

$$P_2 = P_o = 100 \text{ kPa}$$

$$s_2 - s_1 = c_p \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}$$

$$s_2 - s_1 = 1 \times \ln\left(\frac{300}{600}\right) - 0.3\ln\left(\frac{100}{200}\right) = -0.485 \text{ kJ/kgK}$$

$$\Rightarrow \quad s_1 - s_2 = 0.485 \text{ kJ/kgK}$$

$$\Rightarrow \quad \text{Exergy} = 1 \times (600 - 300) - 300 \times 0.485 = 154.5 \text{ kJ/kgK}$$

27. **(c)**

Work is a path function so work done during a process depends on the path followed during the process from initial state to final state.

Volume is point function so change in volume does not depends on the path followed during the process.

28. **(c)**

In case of throttling of real gas,

$$h_1 = h_2$$

$$u_1 + p_1v_1 = u_2 + p_2v_2$$

Internal energy + Flow energy = Constant

Thus, the final outcome of a throttling process will depend on the quantity that increases during the process.

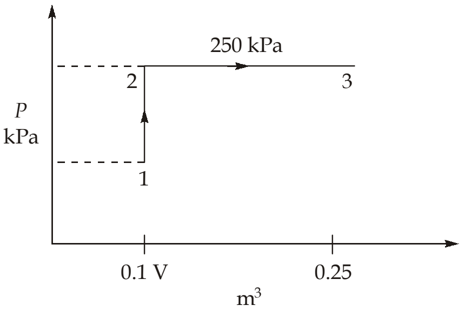
If the flow energy increases ($p_2v_2 > p_1v_1$), it can do so at the expense of the internal energy. As a result, internal energy decreases, which is usually accompanied by a drop in temperature. If the product pv decreases, the internal energy and the temperature of a fluid will increase during throttling process.

29. **(d)**

$$\begin{aligned}\text{Work done in he process} &= \text{Area under line } ABC\\ &= \text{Area under } AB + \text{Area under } BC\\ &= P_A(V_B - V_A) + \left(\frac{P_B + P_C}{2}\right)(V_C - V_A)\\ &= 400\,\text{kPa}(2-1) + \left(\frac{400+200}{2}\right)(4-2) = 1000 \text{ kJ}\end{aligned}$$

30. **(c)**

The process is desired on P-V as



$$\begin{aligned}m &= \frac{PV}{RT}\\ &= \frac{125\times0.1}{(0.287\times300)} = 0.145 \text{ kg}\end{aligned}$$

From ideal gas equation

$$\begin{aligned}\frac{P_1V_1}{T_1} &= \frac{P_3V_3}{T_3}\\ \Rightarrow \qquad \frac{125\times0.1}{300} &= \frac{250\times0.25}{T_3}\\ \Rightarrow \qquad T_3 &= 1500\text{K}\end{aligned}$$

$$\begin{aligned}\text{Work done in the process} &= P_2(V_3 - V_2)\\ &= 250(0.25 - 0.10) = 37.5 \text{ kJ}\end{aligned}$$

from first law of thermodynamics

$$\begin{aligned}Q - W &= \Delta U = m(u_3 - u_1)\\ Q &= W + m(u_3 - u_1)\\ &= 37.5 + 0.145(1114 - 212) = 168.4 \text{ kJ}\end{aligned}$$

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