CLASS TEST

S.No. : 01 JP_ME_09082022

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THERMODYNAMICS

MECHANICAL ENGINEERING

Date of Test : 09/08/2022

ANSWER KEY

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

DETAILED EXPLANATIONS

3. (b)

We know that the temperature at the two scales is related as

$$T(°F) = 1.8\,T(°C) + 32$$

∴ Using the condition,

$$T(°F) = T(°C) = T$$

$$\therefore \quad T = 1.8\,T + 32$$

$$= -0.8\,T = 32$$

$$\therefore \quad T = -40°C$$

5. (a)

Considering compression as a quasi-static polytropic process,

We have, $$P_1V_1^n = P_2V_2^n$$

Index of compression,

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

$$\therefore \quad n = \frac{\ln(1/6)}{\ln(0.03/0.12)}$$

$$\therefore \quad n = \frac{-1.7917}{-1.3863} = 1.292$$

6. (b)

For a reversible cycle,

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$$

$$\frac{W + Q_2}{Q_2} = \frac{T}{200}$$

$$\therefore \quad \frac{40 + (1000/60)}{1000/60} = \frac{T}{200}$$

$$\Rightarrow \quad T = 680\text{ K}$$

8. (b)

$$\eta_{\text{Carnot}} = 1 - \frac{T_L}{T_H} = \frac{\dot{W}_{\text{rev}}}{\dot{Q}_H}$$

$$\therefore \quad \dot{W}_{\text{rev}} = \left(1 - \frac{300}{1200}\right) \times 500$$

$$= 375\text{ kW}$$

Irreversibility rate

$$\dot{I} = \text{Reversible power} - \text{Useful power}$$

$$\therefore \quad \dot{I} = 375\text{ kW} - 180\text{ kW}$$

$$\dot{I} = 195\text{ kW}$$

10. (a)

$$\frac{W_x}{m} = h_1 - h_2 + \frac{V_1^2 - V_2^2}{2 \times 1000}$$

$$\therefore \quad \frac{W_x}{m} = (3230 - 2660) + \frac{160^2 - 100^2}{2 \times 1000}$$

$$\therefore \quad \frac{W_x}{m} = 577.8 \text{ kJ/kg}$$

12. (a)

$$P_1 = 400 \text{ kPa},$$
$$P_2 = 200 \text{ kPa},$$
$$P_{mix} = 250 \text{ kPa}$$
$$N_1 = 3 \text{ Kmol},$$
$$N_2 = 7 \text{ Kmol},$$
$$M_{N2} = 28 \text{ kg/Kmol}$$
$$M_{CO2} = 44 \text{ kg/Kmol}$$
$$N_{mix} = N_1 + N_2 = 10 \text{ Kmol}$$
$$y_1 = \frac{N_1}{N_{mix}} = 0.3$$
$$y_2 = 0.7$$
$$\therefore \quad P_{N2} = y_1 \times P_{mix} = 0.3 \times 250 \text{ kPa} = 75 \text{ kPa}$$

13. (b)

For the work to be maximum, the final temperature should be the geometric mean of the bodies temperatures.

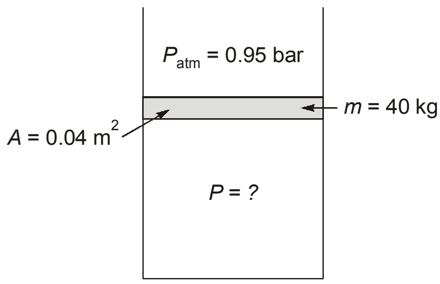
$$\therefore \quad T_f = \sqrt{T_1 T_2}$$
$$= \sqrt{900 \times 400} \; ; \qquad T_f = 600 \text{ K}$$

15. (c)

Availability for a flow process,

$$= (h_1 - h_2) - T_0(S_1 - S_2)$$
$$= 300 - [300 \times (1.1 - 0.7)]$$
$$= 300 - 120$$
$$= 180 \text{ kJ/kg}$$

16. (c)

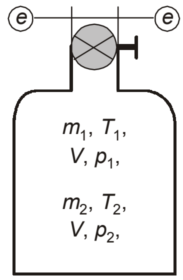


We have:

$$PA = P_{atm} A + W$$
$$P = P_{atm} + mg/A$$
$$P = 0.95 \text{ bar} + \frac{(40 \times 9.81)}{0.04 \times 10^5} \text{bar}$$
$$\Rightarrow \quad P = 1.0481 \text{ bar}$$

17. (a)

Given data:



$$V = 1 \text{ m}^3$$
$$T_1 = 50°C = 323 \text{ K}$$
$$p_1 = 2 \text{ MPa} = 2000 \text{ kPa}$$
$$m_2 = 0.5\, m_1$$
$$p_1 V = m_1 R T_1$$
$$2000 \times 1 = m_1 \times 0.287 \times 323$$

or
$$m_1 = 21.57 \text{ kg}$$
$$m_2 = 0.5 \times 21.57 = 10.78 \text{ kg}$$
$$m_e = m_1 - m_2 = 21.57 - 10.78 = 10.78 \text{ kg}$$

Applying unsteady flow energy equation,

$$\frac{dU}{dt} = m_i h_i + Q - m_e h_e - W_{cv}$$

where
$$Q = 0 \quad \text{adiabatic process}$$
$$W_{cv} = 0 \quad \text{constant volume}$$
$$m_i = 0 \quad \text{no inlet}$$

$$\frac{dU}{dt} = \frac{dm}{dt} \times h_e$$

$$c_v \left\{ T\frac{dm}{dt} + m\frac{dT}{dt} \right\} = \frac{dm}{dt} \times c_p \times T$$

$$T\frac{dm}{dt} + m\frac{dT}{dt} = \frac{dm}{dt} \times \gamma T$$

$$m\frac{dT}{dt} = \frac{dm}{dt} \times (\gamma - 1)T$$

$$\int \frac{dT}{T} = \int \left(\frac{dm}{m}\right) \times (\gamma - 1)$$

$$\ln\frac{T_2}{T_1} = (\gamma - 1)\ln\frac{m_2}{m_1}$$

$$\ln\frac{T_2}{32.3} = 0.4\ln\frac{1}{2}$$

$$T_2 = 244.788 \text{ K}$$

$$p_2 = \frac{m_2 R T_2}{V_2} = \frac{10.78 \times 0.287 \times 244.788}{1} = 757.339 \text{ kPa}$$

18. (b)

$$P \propto \frac{1}{V^2}$$

∴
$$P_1 = \frac{k}{V_1^2}$$

∴
$$P_1 V_1^2 = P_2 V_2^2$$

⇒
$$1000 \times 0.1^2 = 200 \times V_2^2$$

$$\therefore \quad V_2 = 0.223\ \text{m}^3$$

$$\therefore \quad W = \int_1^2 P dv = \int_1^2 \frac{k}{V^2} dV = k\left[\frac{1}{V_1} - \frac{1}{V_2}\right]$$

$$= P_1 V_1^2 \left[\frac{1}{V_1} - \frac{1}{V_2}\right]$$

$$= 1000 \times 0.1^2 \left[\frac{1}{0.1} - \frac{1}{0.223}\right]$$

$$W = 55.28\ \text{kJ}$$

19. (b)

We know by 1st law of thermodynamics,

$$\Delta Q = \Delta U + \Delta W$$

$$(40 - 8) = \Delta U + \frac{-500}{1000}$$

$$\therefore \quad 32 = \Delta U - 0.5$$

$$\Delta U = 32.5$$

$$U_2 - U_1 = 32.5$$

$$U_2 - 10 = 32.5$$

$$\therefore \quad U_2 = 32.5 + 10$$

$$\therefore \quad U_2 = 42.5\ \text{kJ}$$

21. (b)

At triple point all the three phases exist in equilibrium.

$\therefore$ Triple point pressure of liquid and solid X are same.

$$\therefore \quad 12.14 - \frac{3000}{T} = 19.76 - \frac{3500}{T}$$

$$\therefore \quad \text{on solving, } T = 65.61\ \text{K}$$

23. (a)

$$Tds = dH - Vdp$$

Reversible adiabatic, $Tds = 0$

$$dH = Vdp$$

$$h_1 + q = h_2 + W_{cv}$$

$$W_{cv} = h_1 - h_2$$

$$W_{cv} = -Vdp$$

$$P_1 = 0.5\ \text{MPa},$$

$$V_1 = 0.2\ \text{m}^3$$

$$V_2 = 0.05\ \text{m}^3$$

$$PV^{1.3} = \text{Constant}$$

$$\Rightarrow \quad P_2 = P_1\left(\frac{V_1}{V_2}\right)^n$$

$$\Rightarrow \quad P_2 = 0.5 \times \left(\frac{0.20}{0.05}\right)^{1.3} = 3.031\ \text{MPa}$$

$$V = \left(\frac{C}{P}\right)^{1/1.3}$$

$$\int_{H_1}^{H_2} dH = \int_{P_1}^{P_2} Vdp$$

$$H_2 - H_1 = \frac{n[P_2V_2 - P_1V_1]}{n-1} = \frac{1.3[3031 \times 0.05 - 500 \times 0.2]}{1.3-1}$$

$$\Delta H = 223.3 \text{ kJ}$$

24. (d)

$$\dot{Q}_H = \dot{W}_{net} + \dot{Q}_L$$
$$= 6000 + 3500$$
$$= 9500 \text{ kJ/min}$$

Also, $\dot{Q}_A + \dot{Q}_B = \dot{Q}_H$

$$\dot{Q}_A + \dot{Q}_B = 9500 \text{ kJ/min} \quad ...(1)$$

Also, $\dfrac{\dot{Q}_A}{T_A} + \dfrac{\dot{Q}_B}{T_B} = \dfrac{3500}{200}$

∴ $\dot{Q}_A + 2\dot{Q}_B = 14000 \quad ...(2)$

Solving (1) and (2), $\dot{Q}_A = 5000$ kJ/min

$$\dot{Q}_B = 4500 \text{ kJ/min}$$

27. (d)

$$\eta = 0.4$$

also $\eta = \dfrac{W}{Q_1}$

∴ $0.4 = \dfrac{W}{Q_1}$

or $W = 0.4\,Q_1$

Applying energy balance equation for combined system,

$$Q_1 + Q_3 = Q_2 + Q_4$$
$$Q_1 + Q_3 = 3Q_1 \qquad \because Q_2 + Q_4 = 3Q_1 \quad \text{(given)}$$

or $Q_3 = 2Q_1$

COP of the refrigerator,

$$(\text{COP})_R = \frac{Q_3}{W} = \frac{2Q_1}{0.4Q_1} = 5$$

28. (a)

- At critical point, latent heat of vaporization is zero.
- Triple point of water is 273.16 K.
- Normal boiling point of water is the temperature at which vapour pressure is equal to 760 mm Hg.
- The value of Joule's Thompson coefficient for an ideal gas is zero.

29. (c)

$$R_e = \frac{\Sigma mR}{\Sigma m}$$

$$\Rightarrow \quad R_e = 0.77 \times \frac{8.314}{32} + 0.23 \times \frac{8.314}{28}$$

$$\Rightarrow \quad R_e = 0.268 \text{ kJ/kgK}$$

$$[C_v]_e = \frac{R_e}{\gamma - 1} = \frac{0.268}{0.4} = 0.671 \text{ kJ/kg-K}$$

Constant volume process

$$\frac{P_2}{P_1} = \frac{T_2}{T_1}$$

$$\Rightarrow \quad T_2 = 2T_1$$

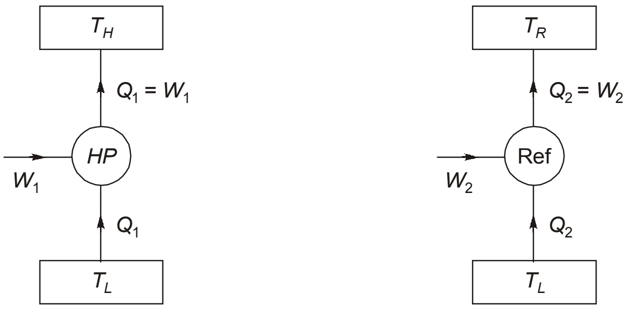
$$\Rightarrow \quad T_2 = 596 \text{ K}$$

$$\text{Heat supplied} = m(C_v)_e \Delta T$$

$$= 2 \times 0.671 \times 298 = 399.916 \text{ kJ}$$

$$\simeq 400 \text{ kJ}$$

30. (c)



For heat pump

$$\frac{T_H}{T_H - T_L} = 5$$

$$\Rightarrow \quad T_H = 5(T_H - T_L)$$

$$\Rightarrow \quad 4T_H = 5T_L$$

$$\Rightarrow \quad T_H = \frac{5}{4}T_L$$

For refrigerator

$$\frac{T_L}{T_R - T_L} = 5$$

$$\Rightarrow \quad T_L = 5(T_R - T_L)$$

$$\Rightarrow \quad 5T_R = 6T_L$$

$$\Rightarrow \quad T_R = \frac{\left(\frac{5}{4}\right)}{\left(\frac{6}{5}\right)} = \frac{25}{24}$$

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