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Thermodynamics

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CLASS TEST 2019-2020

MECHANICAL ENGINEERING

Date of Test : 19/09/2019

ANSWER KEY ➤ Thermodynamics

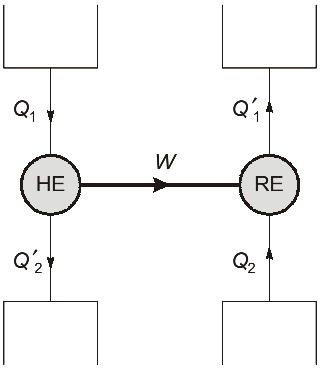
1.	(c)	7.	(a)	13.	(c)	19.	(b)	25.	(c)
2.	(b)	8.	(b)	14.	(b)	20.	(c)	26.	(d)
3.	(d)	9.	(a)	15.	(a)	21.	(a)	27.	(c)
4.	(d)	10.	(d)	16.	(c)	22.	(b)	28.	(d)
5.	(a)	11.	(b)	17.	(c)	23.	(a)	29.	(a)
6.	(a)	12.	(a)	18.	(c)	24.	(a)	30.	(b)

DETAILED EXPLANATIONS

2. (b)

$\int PdV$ work is only valid for a quasi-static process.

3. (d)



$$\frac{W}{Q_1} = \eta_{engine} = 0.3 \quad ...(1)$$

$$\frac{Q_2}{W} = COP_{ref} = 5 \quad ...(2)$$

Multiplying equation (1) and (2)

$$\Rightarrow \quad \frac{Q_2}{Q_1} = 0.3 \times 5 = 1.5$$

$$\Rightarrow \quad Q_1 = \frac{Q_2}{1.5} = \frac{1000}{1.5} \text{ kJ} = 666.67 \text{ kJ}$$

4. (d)

The mixture of air and liquid air is not a pure substance, because the relative proportions of oxygen and nitrogen differ in gas and liquid phases in equilibrium.

6. (a)

If temperature is constant, U will remain unchanged as internal energy for an ideal gas is the function of temperature only.

7. (a)

At steady state fluid properties doesn't change with respect to time at any given point.

8. (b)

$$\text{Efficiency, } \eta = \frac{\text{Area } 1-2-3-1}{\text{Area } a-b-1-3-a} = \frac{\frac{1}{2}(T_3 - T_1)(s_1 - s_2)}{\frac{1}{2}(T_3 + T_1)(s_1 - s_2)} = \frac{T_3 - T_1}{T_3 + T_1}$$

$$= \frac{600 - 200}{600 + 200} = \frac{400}{800} = 0.5$$

11. (b)

Given: P_C = 20 kPa; v_C = 0.002 m^3/kg; T_C = 300 K

We know, $$R = \frac{8P_C v_C}{3T_C} = \frac{8 \times 20 \times 1000 \times 0.002}{3 \times 300} = 0.355 \text{ J/kgK}$$

12. (a)

Given; P = 200 kN/m^2; W_1 = –150 kJ; Q = 50 kJ

We know, $$H = U + PV$$
$$H_1 = U_1 + P_1V_1$$
$$H_2 = U_2 + P_2V_2$$

∴ Change in enthalpy $\Delta H = H_2 - H_1 = (U_2 - U_1) + P(V_2 - V_1)$

Work done by the system,
$$W_2 = P(V_2 - V_1) = 200 \times (5 - 2) = 600 \text{ kJ}$$

From 1st law of thermodynamics,
$$\Delta Q = \Delta U + \Delta W$$
$$\Delta U = \Delta Q - \Delta W = 50 - (-150 + 600) = 50 - 450 = -400 \text{ kJ}$$

So, $$\Delta H = \Delta U + P(V_2 - V_1)$$

∴ $$\Delta H = -400 + 200\,(5 - 2) = -400 + 600 = 200 \text{ kJ}$$

13. (c)

$$c_p = 1 \text{ kJ/kgK}$$
$$c_v = 0.75 \text{ kJ/kgK}$$
$$T = 27°\text{C} = (27 + 273) \text{ K} = 300 \text{ K}$$
$$p = 1 \text{ bar} = 100 \text{ kPa}$$

Gas constant: $$R = c_p - c_v$$
$$= 1 - 0.75 = 0.25 \text{ kJ/kgK}$$

Applying equation of state in term of density,
$$p = \rho R T$$
$$100 = \rho \times 0.25 \times 300$$
$$1 = 0.75\,\rho$$

or $$\rho = \frac{1}{0.75} = \frac{100}{75} = 1.33 \text{ kg/m}^3$$

14. (b)

Heat loss by m_1 = Heat gained by m_2 + Heat gained by m_3

So, $$m_1S(T_1 - T) = m_2S(T - T_2) + m_3S(T - T_3)$$
$$m_1T_1 - m_1T = m_2T - m_2T_2 + m_3T - m_3T_3$$
$$T(m_1 + m_2 + m_3) = m_1T_1 + m_2T_2 + m_3T_3$$

∴ $$T = \frac{m_1T_1 + m_2T_2 + m_3T_3}{m_1 + m_2 + m_3}$$

15. (a)

Heat required to melt 1 kg of iron at 15°C to molten metal at 1650°C = Heat required to raise temperature from 15°C to 1535°C + Latent heat + Heat required to raise the temperature from 1535°C to 1650°C.

$$= 0.502 \times [1535 - 15] + 270 + 0.534\,[1650 - 1535]$$
$$= 1094.5 \text{ kJ/kg}$$

Melting rate = 5×10^3 kg/hr

Rate of heat supply required = $1094.5 \times 5 \times 10^3$ kJ/hr

kW rating of furnace required = $\frac{\text{Heat Rate}}{\text{Furnace Efficiency}} = \frac{1094.5 \times 5 \times 10^3}{0.7}$ kJ/hr

$$= \frac{1094.5 \times 5 \times 10^3}{0.7 \times 3600} \text{ kJ/s}$$

$$= 2171.6 \text{ kW} = 2.17 \text{ MW}$$

16. (c)

Maximum work obtainable from a body and TER,

$$W_{max} = m\left[c_p(T - T_0) + T_0 c_p \ln\left(\frac{T_0}{T}\right)\right]$$

$$= 2\left[1 \times (600 - 300) + 300 \times 1 \times \ln\left(\frac{300}{600}\right)\right]$$

$$= 184.2 \text{ kJ}$$

17. (c)

$$\frac{P}{P_a} = 100 \times \left(\frac{\rho}{\rho_a}\right)^7 - 99$$

$$\Rightarrow \quad \frac{1}{P_a}\frac{dP}{d\rho} = 7 \times 100 \times \frac{\rho^6}{\rho_a^7}$$

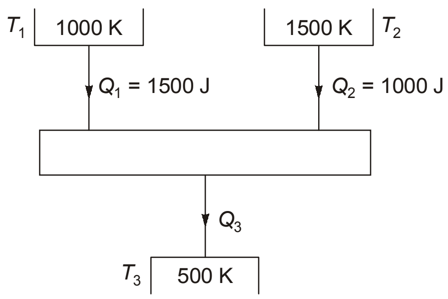
$$\Rightarrow \quad \frac{dP}{d\rho} = 7 \times 100 \times P_a \times \left(\frac{\rho^6}{\rho_a^7}\right)$$

$$\Rightarrow \quad \rho \times \frac{dP}{d\rho} = 7 \times 100 \times P_a \times \left(\frac{\rho}{\rho_a}\right)^7$$

Now, the isothermal bulk modulus (E) is,

$$E = \rho \times \frac{dP}{d\rho} = 7P_a\left[\frac{P}{P_a} + 99\right]$$

18. (c)



For maximum efficiency, $\Delta S = 0$

$$\Rightarrow \quad \oint \frac{dQ}{T} = 0$$

$$\Rightarrow \quad \Delta S = \sum \frac{Q}{T}$$

$$\Rightarrow \quad 0 = \frac{Q_1}{T_1} + \frac{Q_2}{T_2} - \frac{Q_3}{T_3}$$

$$\Rightarrow \qquad 0 = \frac{1500}{1000} + \frac{1000}{1500} - \frac{Q_3}{500}$$

$$\Rightarrow \qquad Q_3 = 1083.33 \text{ J}$$

$$\Rightarrow \qquad W_{max} = Q_1 + Q_2 - Q_3 = 1500 + 1000 - 1083.33 = 1416.67 \text{ J}$$

19. (b)

From heat balance,

$$Q_1 + W_{input} = Q_2$$

$$\Rightarrow \qquad Q_1 = Q_2 - W_{input} = 40 - 10 = 30 \text{ kW}$$

Also, $$\oint \frac{dQ}{T} = 0 \qquad \text{[Reversible]}$$

$$\therefore \qquad \frac{-Q_1}{T_L} + \frac{Q_2}{T_H} = 0$$

$$\Rightarrow \qquad \frac{T_H}{T_L} = \frac{Q_2}{Q_1} = \frac{40}{30} = \frac{4}{3}$$

20. (c)

We know, $$I = W_{maximum} - W_{actual}$$

Now, $$W_{maximum} = \left(1 - \frac{T_2}{1000}\right) \times 500$$

$$\therefore \qquad 150 = \left(1 - \frac{T_2}{1000}\right) \times 500 - 200$$

$$\Rightarrow \qquad 1 - \frac{T_2}{1000} = \frac{350}{500} = 0.7$$

$$\Rightarrow \qquad T_2 = (1 - 0.7) \times 1000 = 0.3 \times 1000 = 300 \text{ K}$$

21. (a)

$$(s_2 - s_1) = c_P \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$$

$$= 1.005 \ln \frac{400}{290} - 0.287 \ln \frac{350}{140}$$

$$= 0.0602 \text{ kJ/Kg-K}$$

Minimum reversible work input required

$$W_{Rev} = \Delta h + \Delta KE - T_O \cdot \Delta s$$

$$= 110.55 + 3.6 - 280 \times 0.0602$$

$$= 97.29 \text{ kJ/kgK}$$

Alternate Method

$$W_{min} = (h_1 - h_2) + \frac{(V_1^2 - V_2^2)}{2} - T_0(s_1 - s_2)$$

$$= -110.55 - 3.6 + 280 \times 0.0602$$

$$= -97.294 \text{ kJ/kg}$$

$$W_{min\ (input)} = 97.294 \text{ kJ/kg}$$

22. (b)

$$h_1 = h_a + x_1(h_b - h_a)$$

$\Rightarrow$ $$h_1 = 25 + 0.6(200 - 25)$$

$$h_1 = 25 + 105 = 130 \text{ kJ/kg}$$

As throttling is an isenthalpic process, so

$$h_1 = h_2$$

$\Rightarrow$ $$h_2 = 130 \text{ kJ/kg}$$

23. (a)

All points as mentioned above may cause irreversibility in a system.

24. (a)

$$\text{As flow work} = pV = 18 \text{ kW}$$

$\Rightarrow$ $$p \times \frac{0.6}{60} = 18000 \text{ J/s}$$

or $$p = 18 \text{ bar} = \mathbf{1800 \text{ kPa}}$$

25. (c)

The metal at T_1 K will come in equilibrium with the lake at temperature T_2 K.

$$(\Delta S)_{metal} = \int_{T_1}^{T_2} \frac{mcdT}{T} = C\ln\frac{T_2}{T_1}$$

$$(\Delta S)_{lake} = \frac{mgZ}{T_2} + \frac{mc(T_1 - T_2)}{T_2}$$

(As potential energy of block dissipates into internal energy of lake)

$$= \frac{gz}{T_2} + \frac{C(T_1 - T_2)}{T_2}$$

$\Rightarrow$ $$(\Delta S)_{universe} = \frac{CT_2\ln\frac{T_2}{T_1} + gz + C(T_1 - T_2)}{T_2}$$

27. (c)

Only one is required to identify the saturation state because in wet region as well as at saturation state both temperature and pressure are dependent property.

29. (a)

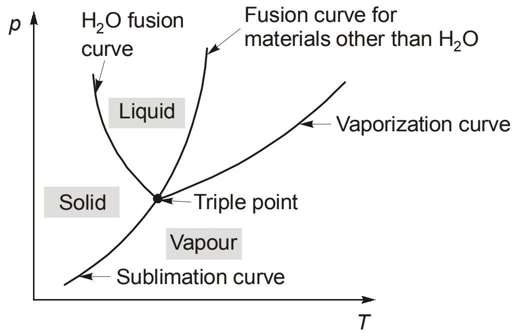
$$\text{Initial availability } (A_1) = Q\left(1 - \frac{T_0}{T_1}\right)$$

$$= 400\left(1 - \frac{300}{1000}\right) = 280 \text{ kJ}$$

availability when heat supplied at 800K

$$A_2 = 400\left(1 - \frac{300}{800}\right) = 250 \text{ kJ}$$

30. (b)



- Slope of fusion curve of water is negative.
- Slope of vaporization curve for all materials is positive.

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