S.No. : 01 GH1_ME_C_030519
Thermodynamics

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CLASS TEST 2019-2020

MECHANICAL ENGINEERING

Subject : Thermodynamics

Date of test : 03/05/2019

Answer Key

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

DETAILED EXPLANATIONS

3. (d)

Reversible steady flow work interaction = $-\int vdp$.

Reversible work transfer in a closed system = $\int pdv$.

4. (d)

$$\delta h = \delta u + \delta(Pv)$$

$$c_P \delta T = \delta u + \delta(Pv)$$

$$c_P = \left(\frac{\delta u}{\delta T}\right) + \left[\frac{\delta(Pv)}{\delta T}\right]_P$$

$$= \left[\frac{\partial}{\partial T}(200 + 0.718T)\right] + \left[\frac{\partial}{\partial T}\{0.287(T + 273)\}\right]_P$$

$$= 0.718 + 0.287 = 1.005$$

7. (c)

Helmholtz function:

$$dH = du + pdv + Vdp = Tds + Vdp \qquad ...(i)$$

Since H is thermodynamic property and exact differential of the type

$$dz = Mdx + Ndy$$

$$\left(\frac{\partial M}{\partial y}\right)_x = \left(\frac{\partial N}{\partial x}\right)_y$$

from (i) and (ii):

$$\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$$

or

$$\left(\frac{\partial P}{\partial T}\right)_S = \left(\frac{\partial S}{\partial V}\right)_P$$

8. (d)

$$\text{Carnot COP} = \frac{T_L}{T_H - T_L} = \frac{273 + 10}{30 - 10} = \frac{283}{20} = 14.15$$

$$\text{Actual COP} = \frac{\text{Heat extracted}}{\text{Work input}} = \frac{18000}{3600} \times \frac{1}{2} = 2.5$$

$$\frac{\text{Actual COP}}{\text{Carnot COP}} = \frac{2.5}{14.15} = 0.1767$$

9. (b)

$$\oint \frac{\delta Q}{T} = +\frac{2000}{1000} - \frac{300}{300} - \frac{250}{200}$$

$$= +2 - 1 - 1.25 = -0.25$$

$\oint \frac{\delta Q}{T} < 0$, so the cycle is irreversible.

11. (b)

$$\eta_{max} = 1-\frac{T_L}{T_H} = 1-\frac{1}{\left(\frac{5}{3}\right)} = 1-\frac{3}{5} = 0.4$$

Actual efficiency, $\eta_{act} = 0.75 \times 0.4 = 0.3$

$$\eta_{act} = \frac{W_{output}}{Q_{supplied}} = 0.3$$

12. (d)

(i) Heat is path function.
(ii) Internal energy is a state function.
(iii) Work is a path function.
(iv) Entropy is a state function.

13. (b)

Given: $P_1 = 300$ kPa, $T_1 = 300$ K, $P_2 = 330$ kPa, $T_2 = ?$

For an ideal gas, PV = RT (for 1 mol)

For constant volume process, $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

$$T_2 = \frac{P_2}{P_1}\times T_1 = 330 \text{ K}$$

Change in internal energy:

$$\Delta U = U_2 - U_1$$
$$= C_V(T_2 - T_1)$$
$$= 21 \times (330 - 300)$$
$$= 21 \times 30 = 630 \text{ J/mol}$$

14. (b)

$$\eta_{HE} = \frac{W}{Q_1} = \frac{500-250}{500}$$

$\Rightarrow$ $W = 500$ kJ

$$COP_{HP} = \frac{Q_3}{W} = \frac{300}{300-250}$$

$$Q_3 = 3000 \text{ kJ}$$

So, $\frac{Q_3}{Q_1} = \frac{3000}{1000} = 3$

16. (b)

F(Helmholtz function) = U – TS
G(Gibbs function) = H – TS
G – F = (H – TS) – (U – TS)
G – F = H – U

For an ideal gas, H = $f(T)$, U = $f(T)$

So, G – F = $f(T)$

17. (d)

$$P_2 A = P_{atm} A + k x_2$$

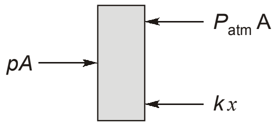
$$P_2 = P_{atm} + \frac{kx_2}{A}$$

$$V_2 - V_1 = A(x_2 - x_1)$$

$$x_2 = \frac{V_2 - V_1}{A} \quad (x_1 = 0)$$

$$x_2 = \frac{(3-2)\times 10^{-3}}{0.02} = \frac{1\times 10^{-3}}{0.02} = 0.05 \text{ m}$$

$$P_2 = 110 + \frac{20\times 10^3 \times 0.05 \times 10^{-3}}{0.02} = 110 + 50 = 160 \text{ kPa}$$



FBD of piston of final position

18. (a)

SFEE can be written as

$$h_1 + \frac{V_1^2}{2} + gZ_1 + q = h_2 + \frac{V_2^2}{2} + gZ_2 + w$$

For adiabatic passage, $q = 0,\ w = 0$

Neglecting gravitational effect, $Z_1 = Z_2$

$$\frac{V_2^2}{2} = \frac{V_1^2}{2} + h_1 - h_2$$

$$V_2^2 = V_1^2 + 2c_P(T_1 - T_2)$$

$$= (150)^2 + 2 \times 1005\,(500 - 510)$$

$$V_2^2 = 2400$$

$$V_2 = 48.9898 \text{ m/s} \approx 49 \text{ m/s}$$

Velocity decreases and pressure increases. So the device is diffuser.

19. (d)

$$\Delta S_E = +\frac{600}{300} = +2 \text{ J/K} \quad \text{(Heat is added to surrounding)}$$

$$(\Delta S)_{universe} > 0$$

$$\Delta S_E + \Delta S_F > 0$$

$$\Delta S_F > -2 \text{ J/K}$$

20. (c)

Throttling is isenthalpic process for which

$$h_1 = h_2$$

$$= h_{f2} + x_2(h_{g2} - h_{f2})$$

$$x_1 = \frac{h_1 - h_{f2}}{h_{g2} - h_{f2}} = \frac{750 - 500}{2500 - 500} = \frac{250}{2000}$$

$$x_2 = 0.125 \text{ or } 12.5\%$$

21. (c)

$$R = \frac{\bar{R}}{M_{CO_2}} = \frac{8.314 \times 1000}{44} = 188.95 \text{ J/kg K}$$

$$Z = \frac{PV}{RT} = \frac{4.05 \times 10^6 \times 0.0143}{188.95 \times 350} = 0.87574$$

22. (d)

$$R_{H_2} = \frac{\bar{R}}{M_{H_2}} = \frac{8.314}{2} = 4.157 \text{ kJ/kg K}$$

Specific entropy change, $\Delta s = s_2 - s_1$

$$= c_V \ln\frac{T_2}{T_1} + R\ln\frac{V_2}{V_1}$$

$$= 10.389\ln\frac{650}{350} + 4.157\ln\frac{0.2}{1.0}$$

$$= 6.4312 - 6.69 = -0.2588 \text{ kJ/kg K}$$

$$\Delta S = m\,\Delta s$$

$$= 0.2 \times -0.2588$$

$$= -0.05176 \text{ kJ/K}$$

$$= -51.76 \text{ J/K}$$

23. (a)

We know that Clausius-Clapeyron equation can be written as

$$\frac{dP}{dT} = \frac{h_{fg}P}{RT^2}$$

$$\int\frac{dP}{P} = \int\frac{h_{fg}}{RT^2}dT$$

$$\ln P = -\frac{h_{fg}}{RT} + C_1 \qquad [C_1 \text{ is constant of integration}]$$

After rearranging, we get

$$P_{sat} = C\exp\left[-\frac{h_{fg}}{RT_{sat}}\right]$$

$T_{sat} = 100°\text{C} = 273.15 + 100 = 373.15$ K, $P_{sat} = 101.35$ kPa

$$101.35 = C\exp\left[-\frac{2257.06}{0.46152 \times 373.15}\right]$$

$$101.35 = C\exp[-13.106]$$

$$C = 4.98510 \times 10^7 \text{ kPa}$$

Now, we have to find P_{sat} for $T = 105°\text{C} = 378.15$ K

$$P_{sat} = 4.98510 \times 10^7 \exp\left[-\frac{2257.06}{0.4612 \times 378.15}\right] = 120.527 \text{ kPa}$$

24. (a)

Frictional force, $F_f = 0.1\,F_N = 0.1 \times mg$

$= 0.1 \times 30 \times 9.81 = 29.43$ N

Work done against friction is $W = F_f\,\Delta x$

$= 29.43 \times 8 = 235.4$ J

All work done against friction is heat transferred to the atmosphere:

$$Q = W = 235.4 \text{ J}$$

$$\Delta S = \frac{Q}{T_{atm}} = \frac{235.4}{298.14} = 0.7895 \text{ J/K}$$

25. (a)

$$P = \frac{RT}{v-b} - \frac{a}{TV^2}$$

$$RT = \left(P + \frac{a}{TV^2}\right)(v-b)$$

$$\frac{RT}{P} = v + \frac{a}{PvT} - b - \frac{ab}{Pv^2T}$$

$$RT - Pv = \frac{a}{vT} - bp - \frac{ab}{v^2T}$$

$$Pv = RT - \frac{a}{vT} + bp + \frac{ab}{v^2T}$$

The last three terms of the equation are very small, except at very high pressures and small volume.

Hence, substituting $v = \frac{RT}{p}$

$$Pv = RT - \frac{ap}{RT^2} + bp + \frac{abp^2}{R^2T^3}$$

$$\left[\frac{\partial(Pv)}{\partial P}\right]_T = -\frac{a}{RT^2} + b + \frac{2abp}{R^2T^3} = 0$$

When $P = 0$, $T = T_B$, the Boyle temperature

$$\frac{a}{RT_B^2} = b$$

$$T_B = \sqrt{\frac{a}{bR}}$$

26. (b)

Decrease in availability or exergy

$$\psi_1 - \psi_2 = (h_1 - h_2) - T_0(s_1 - s_2) + \frac{V_1^2 - V_2^2}{2}$$

$$= C_P(T_1 - T_2) - T_0\left[R\ln\frac{P_2}{P_1} - C_P\ln\frac{T_2}{T_1}\right] - \frac{V_2^2}{2}$$

$$= 1.005(27-137) - 300\left[0.287\ln 3.5 - 1.005\ln\frac{410}{300}\right] - \frac{90^2}{2000}$$

$$= -110.385 - 300\,[0.3595 - 0.31347] - 4.05$$

$$= -110.385 - 13.809 - 4.05$$

$$= -128.244 \text{ kJ/kg}$$

27. (b)

$$\frac{n-1}{n} = \frac{\ln\left(\frac{T_2}{T_1}\right)}{\ln\left(\frac{P_2}{P_1}\right)} = \frac{\ln\left(\frac{393}{293}\right)}{\ln\left(\frac{6}{1.5}\right)}$$

$$= \frac{0.293637}{1.3863} = 0.211814$$

$$1-\frac{1}{n} = 0.211814$$

$$\frac{1}{n} = 1-0.211814 = 0.7881857$$

$$n = 1.2687$$

30. (c)

Maximum work obtained at

$$\sqrt{T_1 T_2} = \sqrt{650\times 350} \approx 477 \text{ K}$$

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