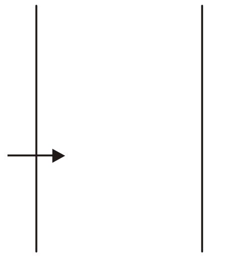
Class Test Solution (Thermodynamics) 10-04-2019
Answer key

1.	(a)	9.	(d)	17.	(d)	25.	(c)	33.	(c)
2.	(d)	10.	(d)	18.	(b)	26.	(a)	34.	(b)
3.	(c)	11.	(c)	19.	(a)	27.	(c)	35.	(b)
4.	(b)	12.	(a)	20.	(d)	28.	(b)	36.	(c)
5.	(d)	13.	(c)	21.	(b)	29.	(a)	37.	(b)
6.	(d)	14.	(a)	22.	(a)	30.	(c)	38.	(b)
7.	(a)	15.	(d)	23.	(c)	31.	(a)	39.	(b)
8.	(b)	16.	(d)	24.	(c)	32.	(d)	40.	(c)

1. (a)



$\dot{\delta}_{gen} = (\Delta s)_{univ}$

$= \frac{-600}{(20+273)} + \frac{600}{(5+273)}$

= 0.11 W/k

2. (d)

$(\Delta s)_{iso} = m\left[R\ell n\left|\frac{T_2}{T_1}\right| - R\ell n\left|\frac{P_2}{P_1}\right|\right]$

$= mR\,\ell n\frac{P_1}{P_2}$

= –ve $\quad (\therefore P_1 < P_2)$

3. (d)

$C_P = C_V + R = 1.0$ kJ/kgK

$dh = C_P dT = 100$ kJ/kg

4. (b)

$du = C_V dT = 0.7\,(100) = 70$ kJ/kg

5. (d) W = ?

6. (d) Q = ?

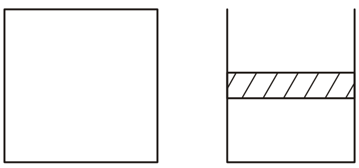
7. (a) $(PV)_f - (PV)_i = RT_f - RT_i$

$= R(T_f - T_i) = 0.3(100) = 30$ kJ/kg

8. (b) Rigid tank; dv = 0

$W = \int P \cdot dV = 0$

9. (d)



$Q_V = mC_V\Delta T \qquad Q_P = mC_P\Delta t$

$Q_P - Q_V = m(C_P - C_V)\Delta T = mR\Delta T$

$= n\bar{R}\,\Delta T = 3 \times 8.314 \times 10 = 249$ kJ

10. (d) Throttling

h = constant

Air $\rightarrow$ ideal gas

and for an ideal gas h = f(temp.) only

T = constant

11. (c) $H_1 + Q = H_2 + Q$

$\Rightarrow W = (H_1 - H_2) + Q$

$= \dot{m}C_P((T_1 - T_2) + Q$

= 0.1 × 1.005(1500 – 900) – 15

= 45 kW

12. (a) Heat gained by cold air = heat lost by hot air

$\Rightarrow \dot{m}_c C_{Pc}(T_f - T_c) = \dot{m}_h C_{Ph}(T_h - T_f)$

$\Rightarrow 4(T_f - 7) = 3(70 - T_f)$

$\Rightarrow 4T_f - 28 = 210 - 3T_f$

$\Rightarrow 7T_f = 238 \Rightarrow T_f = \frac{238}{7} = 34°C$

13. (c) By energy conservation principle;

Power consumed by air conditioner is dissipated as heat in the room and hence room will get heated.

14. (a) $T_2 = \sqrt{T_1T_3} = \sqrt{1300 \times 300} = 625$ k

$x = 1 - \frac{T_2}{T_1} = 1 - \frac{T_3}{T_2} \Rightarrow T_2 = \sqrt{T_1T_3}$

15. (d) $(COP)_{HP} = 1 + (COP)_R = 1 + 3.4 = 4.4$

16. (d) $Q_2 = 32$ kJ/s

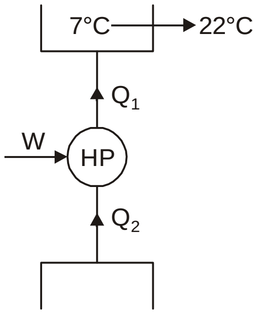
$T_L = 20°C,\ T_h = 35°C$

$(COP)_{rev} = \frac{T_L}{T_h - T_L} = \frac{(20+273)}{35-20}$

$= 19.533 = \frac{Q_2}{W}$

$\Rightarrow W_{i/p} = \frac{32}{19.533}$ kW $= 1.638 = 1.64$

17. (d)



Heat pump

COP = 3.2

$m_{air} = 1200$ kg; $P_{i/p} = 5$ kW

$T_L = 7°C$; $T_h = 22°C$

$\text{COP} = \frac{Q_1}{W} \Rightarrow Q_1 = (\text{COP}) \times W_{i/p}$

$= 3.2 \times 5 = 16$ kW

Total heat to be added to the room

$= \dot{m}_{air}(C_P)_{air}(22-7) = 1200 \times 1.005 \times 15$

$= 18090$ kJ

Time required $= \frac{18090}{16}$ kJ / s

$= 18.8$ minute

18. (b) Constant pressure process

$W = P \cdot \Delta V$

$\frac{V_2}{V_1} = \frac{T_2}{T_1} \Rightarrow V_2 = V_1 \times \frac{T_2}{T_1}$

$= 0.1 \times \frac{600}{300} = 0.2 \text{ m}^3$

$W = 300 \times (0.2 - 0.1) = 30$ kJ

Power deliversed to piston $= \frac{30 \text{ kJ}}{30 \text{ sec}} = 1$ kW

19. (a) $P_1 = P_0 + CV^{1/2}$; $200 = 100 + C(0.1)^{1/2}$,

$C = 316.23$

$225 = 100 + CV_2^{1/2} \Rightarrow V_2 = 0.156 \text{ m}^3$

$P_2V_2 = mRT_2 = \frac{P_1V_1}{T_1}T_2$

$\Rightarrow T_2 = \left(\frac{P_2V_2}{P_1V_1}\right)T_1 = \frac{225 \times 0.156 \times 303.15}{200 \times 0.1}$

$= 532 \text{ K} = 258.9°C$

20. (d) $W_{12} = \int P\,dV = \int (P_0 + CV^{1/2})\,dV$

$= P_0(V_2 - V_1) + C \times \frac{2}{3} \times \left(V_2^{3/2} - V_1^{3/2}\right)$

$= 100(0.156 - 0.1) + 316.23 \times \frac{2}{3} \times$

$(0.156^{3/2} - 0.1^{3/2})$

$= 5.6 + 6.32 = 11.9$ kJ

21. (b) Continuity eq. : $\dot{m}_i = \dot{m}_e = (AV/v)$

Energy eq. : $\dot{m}(h_i + \frac{1}{2}V_i^2) = \dot{m}\left(\frac{1}{2}V_e^2 + h_e\right)$

$h_e - h_i = C_p(T_e - T_i) = \frac{1}{2}V_i^2 - \frac{1}{2}V_e^2$

$= \frac{1}{2}\left(\frac{900 \times 1000}{3600}\right)^2 - \frac{1}{2}(80)^2$

$= 28050$ J/kg $= 28.05$ kJ/kg

$\Delta T = \frac{28.05}{1.004} = 27.9$

$\Rightarrow T_e = -5 + 27.9 = 22.9°C$

22. (a) Now use the continuity eq.:

$\frac{A_iV_i}{v_i} = \frac{A_eV_e}{v_e} \Rightarrow v_e = v_i\left(\frac{A_eV_e}{A_iV_i}\right)$

$v_e = v_i \times \frac{0.8 \times 80}{1 \times 250} = v_i \times 0.256$

By ideal gas equation:

$PV = RT$

$$\frac{P_e}{P_i} = \frac{T_e}{T_i} \times \frac{v_i}{v_e} = \frac{(22.9+273)}{(-5+273)} \times \frac{1}{0.256}$$

$= 4.313$

$P_e = 4.313 \times 50 = 215.7$ kPa

23. (c)

$$(\Delta S)_{sum} = \frac{5 \times 3600}{293} = 61.4 \text{ kj/k}$$

$$(\Delta S)_{sys} = 0$$

$$(\Delta S)_{univ} = (\Delta S)_{sys} + (\Delta S)_{sum}$$

$= 61.4$ kJ/k

24. (c)

$$W = P\left(\frac{1}{2} - \frac{1}{1}\right)$$

$$(V_2 - V_1) = \frac{54}{600} = 0.09 \text{ m}^3$$

$\Rightarrow$ $V_2 = 0.09 + 0.001 = 0.1 \text{m}^3$

$$P_2V_2 = mRT_2$$

$$\Rightarrow \quad T_2 = \frac{P_2V_2}{mR} = \frac{P_2V_2}{\left(P_1V_1/T_1\right)}$$

$= 2900$

25. (c) By 1st law of thermodynamic for a closed system

$$Q = \Delta V + W$$

$= M(V_2 - V_1) + W$

$= MC_V (T_2 - T_1) + W$

$= 223.9$

26. (a)

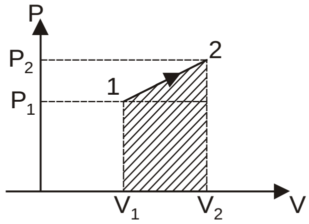
$W = \int P.dv$ = Area under curve on P – V diagram

$$= \left(\frac{P_2 + P_1}{2}\right)(V_2 - V_1)$$

$$V_1 = \frac{MRT_1}{P_1} = \frac{1.5 \times 0.287 \times 300}{160}$$

$= 0.8072 \text{ m}^3$

$V_2 = 2V_1$



$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow P_2 = P_1 \times \left(\frac{V_1}{V_2}\right) \times \left(\frac{T_2}{T_1}\right) = 160 \times \left(\frac{1}{2}\right) \times \left(\frac{900}{300}\right)$$

$= 240$KPa

$$\text{Work transfer} = \left(\frac{240+160}{2}\right)(0.8072)$$

$= 161.4$ kJ

27. (c) Heat transfer

$$Q = \Delta U + W$$

$= MC_V (T_2 - T_1) + W$

$= 1.5 \times 0.718 \times (900 - 300) + 161.4$

$= 807.6$ KJ

28. (b) Throttling

By continuity equation:

$$\rho AV = \text{constant}$$

$$\frac{AV}{v} = \text{constant}$$

$\therefore$ for ideal gas: $v = \frac{RT}{P}$

$$\frac{AV}{\left(\frac{RT}{P}\right)} = \text{constant}$$

R,V, and T are constant [for an ideal gas undorgoins throttling Temperature remains constant]

PA = contant

$P_iA_i = P_eA_e$

$$\Rightarrow \quad \frac{D_e}{D_i} = \sqrt{\frac{P_i}{P_e}} = \left(\frac{1.2}{1}\right)^{1/2}$$

$= 3.464$

29. (a) By SREE

$$h_i + \frac{C_1^2}{2000} + q_{cv} = h_e + \frac{C_e^2}{2000} + W_{cv}$$

$$q_{cv} = 0;\ h_i = h_e$$

(same temperature and pressure)

$$C_i \approx 0$$

$$\text{Work input} = -W_{cv} = \frac{C_e^2}{2000}$$

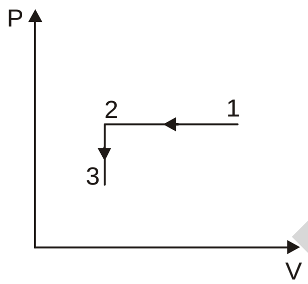
$$= \frac{(18)^2}{2000} = 0.162 \text{ KJ/kg}$$

$$\text{Total power input} = 0.2 \text{ kg/s} \times 0.162 \text{kJ/g}$$

$$= 0.032 \text{ kW}$$

$$= 32.9\text{W}$$

30. (c)



$$T_2 = \frac{3}{4}T_1\ ;\ T_3 = \frac{T_1}{2}$$

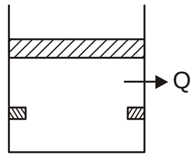
$$\frac{V_2}{V_1} = \frac{T_2}{T_1} \Rightarrow V_2 = \frac{3}{4}V_1$$

$P_2 = P_1$

$$\frac{P_3}{P_2} = \frac{T_3}{T_2} \Rightarrow P_3 = P_2 \times \frac{T_{1/2}}{3/4\,T_1}$$

$$\frac{P_3 = P_1 \times \frac{2}{3}}{V_3 = V_2 = \frac{3}{4}V_1} \Rightarrow \boxed{\frac{V_3}{V_1} = \frac{3}{4}} = 0.75$$

31. (a)



Work done on gas by piston

$$= W_{1\text{-}2} + W_{2\text{-}3} = P_1(V_1 - V_2) + 0$$

$$= P_1V_1\left(1 - \frac{3}{4}\right) = \frac{RT_1}{4}$$

32. (d)

Total heat transferred from gas

$$= Q_{1\text{-}2} + Q_{2\text{-}3} = \dot{m}C_P(T_1 - T_3) + \dot{m}C_V(T_2 - T_3)$$

$$= C_PT_1\left(1 - \frac{3}{4}\right) + C_VT_2\left(1 - \frac{T_3}{T_2}\right)$$

$$= \frac{C_PT_1}{4} + C_V\left(\frac{3}{4}T_1\right)\left(1 - \frac{\frac{T_1}{2}}{\frac{3}{4}T_1}\right)$$

$$= \frac{C_PT_1}{4} + \frac{C_VT_1}{4} = (C_P + C_V)\frac{T_1}{4}$$

33. (c)

34. (b)

Heat lost by water = heat gained by ice

$0.45 \times 4.18 \times (20 - 0) = m_{ice} \times 334$

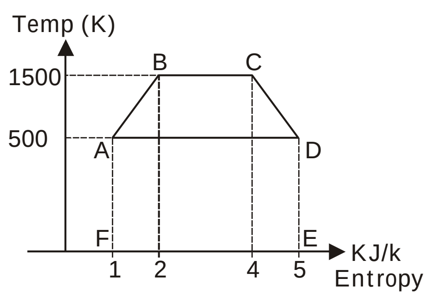
$$\Rightarrow \boxed{m_{ice} = 113 \text{ g}}$$

35. (b)

$2 \text{ kJ/s} \times (10 \times 60)\text{sec} = 300 + m_w C_{Pw}(\Delta T)$

$$\Rightarrow \Delta T = \frac{900}{5 \times 4.18} = 43.1°\text{C}$$

36. (b)



Work done = Area ABCD

$= \frac{1}{2}(BC + AD) \times 1000$

$= 3000 kJ$

Heat rejected = Area ADEF

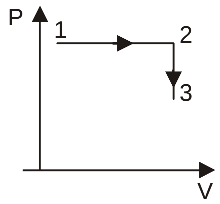
$= 500\ (5 - 1)$

$= 2000\ kJ$

$Q_s = W + Q_R = 5000\ kJ$

$\eta = \frac{W_{net}}{Q_s} = \frac{3000}{5000} = 0.60$

37. (b)



$\frac{T_2}{T_1} = \frac{V_2}{V_1} = 2$

$T_2 = 2T_1 = 1200K$

$T_3 = 600\ K$

$\frac{T_3}{T_2} = \frac{P_3}{P_2}$

$P_3 = \frac{T_3}{T_2} \times P_2 = \frac{600}{1200} \times 200 = 100\ KPa$

38. (b) Process 1-2,

Constant pressure process

$W_{1-2} = P(V_2 - V_1)$

$= P(2V_1 - V_1)$

$= RT_1$

$= 172.2\ KJ/kg$

$Q_{1-2} = C_p(T_2 - T_1)$

$= 1.005(1200–600)$

$= 603\ KJ/kg$

Process 2 – 3,

$W_{2-3} = 0$

$Q_{2-3} = C_v(T_3 - T_2)$

$= 0.718(–600)$

$= –430.8\ kJ$

Total work transfer $= W_{1-2} + W_{2-3}$

$= 172.2 kJ$

39. (b) Total heat transfer $= 603 - 430.8$

$= 172.2\ kJ$

40. (c) $W = \int P.dv$

P → Intensive property

dv → change in extensive porperty