CLASS TEST

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CLASS TEST 2019-20

MECHANICAL ENGINEERING

Subject : Thermodynamics

Date of test : 10/02/19

Answer Key

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

Detailed Explanations

1. (c)
Quasi means almost. Every state in quasi-static process through which system passes remains almost in equilibrium.

4. (b)
The maximum inversion temperature of hydrogen and helium are 200 K and 24 K, so on throttling, the temperature of both will increase.

5. (a)
For charging of an evacuated adiabatic chamber, $T_f = \gamma T_L$
where T_f = final temperature

$$\gamma = \frac{c_P}{c_V}$$

T_L = supply line temperature

6. (b)

$$1-\frac{T_2}{700} = 1-\frac{448}{T_2}$$

$$T_2 = \sqrt{700\times 448} = 560\text{K}$$

7. (b)

$$dW = \int_{V_1}^{V_2} pdV = p(V_f - V_i) = 0.1 \times (0.15 - 0.3)$$

$$= 0.1 \times (-0.15) = 0.015 \text{ MJ} = -15 \text{ kJ}$$

$$dQ = -35 \text{ kJ};$$

$$dQ = dU + dW$$

$$-35 = dU - 15$$

$$dU = -20 \text{ kJ}$$

8. (c)

$$W_{net} = (T_1 - T_2)(s_1 - s_2)$$

$$= (723 - 353)(2.5)$$

$$= 925 \text{ kJ/kg}$$

9. (a)
At constant entropy, the phase change of a saturated liquid does not take place by increasing the temperature. Thus, the resulting state will also be a liquid.

10. (d)

$$Tds = dh - vdp$$

At constant pressure $dp = 0$

So, $$\left(\frac{dh}{ds}\right)_P = T$$

13. (d)

Decrease in potential energy = Increase in heat energy

$$mgh = mc\Delta t$$

$$1 \times 9.81 \times 100 = 1 \times 4186 \times \Delta t$$

$$\Delta t = \frac{981}{4186} = 0.234°\text{C}$$

14. (b)

$$\text{Loss of available energy} = Q_1 T_0 \frac{(T_1 - T_2)}{T_1 T_2} = \frac{2000 \times 300(600 - 400)}{600 \times 400} = 500 \text{ kJ}$$

18. (b)

$$\Delta PE = mg(h_2 - h_1) = 50 \times 9.81 \times 40 = 19620 \text{ J}$$

$$\Delta KE = \frac{1}{2} m\left(V_2^2 - V_1^2\right) = \frac{1}{2} \times 50 \times (30^2 - 10^2) = 20{,}000 \text{ J}$$

$$Q_{1-2} = 30{,}000 \text{ J}$$

$$W_{1-2} = \text{Work delivered} - \text{Work received}$$

$$= 0.002 \times 1000 \times 3600 - 4500 = 2700 \text{ J}$$

For non-flow process,

$$Q_{1-2} = W_{1-2} + dE$$

$$Q_{1-2} = W_{1-2} + dU + \Delta KE + \Delta PE$$

$$dU = 30{,}000 - 2700 - 20{,}000 - 19620$$

$$= -12320 \text{ J}$$

19. (a)

From the relation,

$$Tds = du + pdV$$

$$ds = C_v \frac{dT}{T} + \frac{P}{T} dV = C_v \frac{dT}{T} + R \frac{dV}{V}^{\nearrow 0}$$

Upon integration,

$$s_2 - s_1 = \int Cv \frac{dT}{T}$$

$$= \int_{273}^{800} \left(\frac{0.65}{T} + 0.0002\right) dT$$

$$= 0.65 \, ln \frac{800}{273} + 0.0002(800 - 273)$$

$$= 0.6988 + 0.1054 = 0.8042 \text{ kJ/kgK}$$

20. (b)

Revolutions made by the workpiece in 10 min,

$$N = 180 \times 10 = 1800$$

$$\text{Torque, } T = \text{Force} \times \text{radius} = 100 \times \frac{0.3}{2} = 15 \text{ Nm}$$

Work done on the work piece

$$\delta W = 2\pi NT = 2\pi \times 1800 \times 15 = 169646 \text{ Nm(or J)}$$

(work will be –ve sign since it is being done on the work piece)

$$\delta Q = \delta W + \delta U$$
$$\delta Q = -169.64 + 125 = -44.64 \text{ kJ}$$

21. (b)

$$\text{Internal energy } U = f(T)$$
$$= \text{Constant for isothermal process}$$
$$\therefore \quad U_1 = U_2$$

Change in Gibbs free energy, for an isothermal process is

$$\Delta G = RT\, ln\left(\frac{P_2}{P_1}\right)$$

$$\text{For } P_2 > P_1, \Delta G = G_2 - G_1 > 0$$
$$\therefore \quad G_2 > G_1$$

22. (d)

$$\text{Gas constant, } R = \frac{R_{mol}}{\text{Molecular mass}} = \frac{8314}{28} = 296.93 \text{ J/kg.K}$$

$$m = \frac{P_1V_1}{RT_1} = \frac{1\times10^5 \times 0.03}{296.93 \times 290} = 0.0348 \text{ kg}$$

$$\text{Change in entropy, } (S_2 - S_1) = m\left[C_p\, ln\frac{T_2}{T_1} - R\, ln\frac{P_2}{P_1}\right] \qquad [\text{isothermal process} \rightarrow T_1 = T_2]$$

$$(S_2 - S_1) = -mR\, ln\frac{P_2}{P_1}$$

$$= -0.0348 \times 296.93\, ln\frac{4}{1}$$

$$= -14.324 \text{ J/K}$$

23. (c)

$$\text{Work done in 2.5 hrs} = VIT$$

$$= \frac{12 \times 8 \times 2.5}{1000} \times 3600 = 864 \text{ kJ}$$

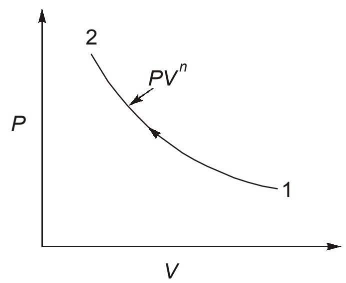
Non-flow energy equation,

$$\delta Q = \delta W + dU$$
$$\delta Q = 864 - 1250 = -386 \text{ kJ}$$

24. (a)

$$\left(\frac{P_2}{P_1}\right) = \left(\frac{T_2}{T_1}\right)^{\frac{n}{n-1}}$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$



$$l n\left(\frac{T_2}{T_1}\right) = \frac{n-1}{n} l n\left(\frac{P_2}{P_1}\right)$$

$$\frac{n-1}{n} = \frac{l n(T_2/T_1)}{l n(P_2/P_1)}$$

$$\frac{n-1}{n} = \frac{l n(393/293)}{l n(6/1.5)} = 0.2118$$

So, $n = 1.2687$

25. (d)

We know efficiency of Carnot engine operating between temperature limits T_H and T_L is

$$\eta = 1-\frac{T_L}{T_H}$$

$$\therefore \quad 2\left(1-\frac{T_L}{T_H}\right) = 1-\frac{T_L}{T_H'}$$

$\therefore$ On solving,

$$T_H' = \frac{T_L T_H}{2T_L - T_H}$$

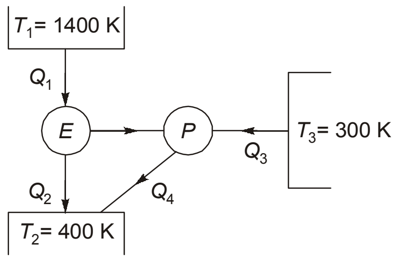
26. (c)

For the reversible engine:

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

For the reversible pump:

$$\frac{Q_3}{Q_4} = \frac{T_3}{T_4}$$



Since, the entire output of the heat engine is utilized to drive the pump,

$$Q_1 - Q_2 = Q_4 - Q_3$$

$$Q_1 - \frac{T_2}{T_1}Q_1 = Q_4 - \frac{T_3}{T_4}Q_4$$

$$\frac{Q_1}{Q_4} = \frac{T_1}{T_4}\left(\frac{T_4 - T_3}{T_1 - T_2}\right)$$

$$\frac{Q_1}{Q_4} = \frac{1400}{400}\left(\frac{400-300}{1400-400}\right) = 0.35$$

Heat supplied to the reservoir at 400 K,

$$100 = Q_2 + Q_4$$

$$100 = Q_1\frac{T_2}{T_1} + \frac{Q_1}{0.35}$$

$$100 = Q_1\frac{400}{1400} + \frac{Q_1}{0.35} = 3.14\, Q_1$$

$\therefore$ Energy taken from the reservoir at 1400 K,

$$Q_1 = \frac{100}{3.14} = 31.82 \text{ kJ/s}$$

27. (d)

From the principle of energy conservation,

heat given by hot gases = heat gained by water

$$(mC_p\Delta t)_{gas} = (mC_p\Delta t)_{water} = \text{heat transfer } (Q)$$

$$m_g \times 1.08 \times (180 - 80) = 0.25 \times 4.186 \times (60 - 30) = Q$$

$$\therefore \quad m_g = 0.2907 \text{ kg and } Q = 31.395 \text{ kJ/s}$$

$$(dS)_{gases} = m_g C_{pg}\, ln\frac{T_{2g}}{T_{1g}}$$

$$= 0.2907 \times 1.08 \times ln\left(\frac{80+273}{180+273}\right) = -0.078 \text{ kJ/K}$$

$$(ds)_{water} = m_w C_{pw}\, ln\frac{T_{2w}}{T_{1w}} = 0.25 \times 4.186 \times ln\left(\frac{60+273}{30+273}\right)$$

$$= 0.098 \text{ kJ/K}$$

∴ Entropy production as a result of heat transfer is

$$(ds)_{net} = (ds)_{gases} + (ds)_{water}$$

$$= -0.078 + 0.098 = 0.02 \text{ kJ/K}$$

Rate of increase in unavailable energy (or loss of available energy)

$$= T_0(ds)_{net}$$

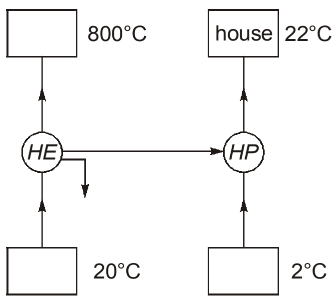
$$= (273 + 27) \times 0.02$$

$$= 6 \text{ kJ/s}$$

28. (d)

$$(COP)_{heat\ pump} = \frac{T_H}{T_H - T_L}$$

$$= \frac{22+273}{20} = 14.75$$



$$\text{Power input to the heat pump} = \frac{Q_H}{COP}$$

$$= \frac{62000}{14.75} = 4203 \text{ kJ/h}$$

$$(W_{input})_{HP} = \frac{1}{2} W_{HE}$$

$$W_{HE} = 8406 \text{ kJ/h}$$

$$\eta_{HE} = 1 - \frac{T_L}{T_H} = 1 - \frac{293}{1073} = 0.727$$

$$Q_S \text{ for the heat engine} = \frac{W_{HE}}{\eta_{th}} = \frac{8406}{0.727} = 11560 \text{ kJ/h}$$

Heat supply to the heat engine $= \frac{11560}{3600} = 3.21\,\text{kW}$

29. (a)

$$(\Delta S)_{universe} = (\Delta S)_{system} + (\Delta S)_{surrounding}$$
$$= mC\, ln\frac{T_2}{T_1} - \frac{Q}{T}$$
$$= 1 \times 4.18\, ln\frac{363}{273} - \frac{1 \times 4.18(90-0)}{363}$$
$$= 1.191 - 1.036$$
$$= 0.155\ \text{kJ/K}$$

30. (d)

In the absence of any other information regarding v_g and v_f, the Clausius Clapeyron equation can be used to determine the saturation temperature corresponding to the given pressure.

$$\left(\frac{\partial P}{\partial T}\right)_{sat} = \frac{h_{fg} \cdot P}{RT^2}$$

$$\Rightarrow \quad [ln\, P]_{P_1}^{P_2} = \frac{h_{fg}}{R}\left[-\frac{1}{T}\right]_{T_1}^{T_2}$$

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

$$\Rightarrow \quad ln\frac{250}{101.325} = \frac{2257}{\frac{8.314}{18}}\left[\frac{1}{373} - \frac{1}{T_2}\right]$$

$$\Rightarrow \quad 0.903 = 4886.45\left[\frac{1}{373} - \frac{1}{T_2}\right]$$

$$T_2 = 400.6\ \text{K}$$
$$t_2 = 127.6^\circ\text{C}$$

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