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THERMODYNAMICS

MECHANICAL ENGINEERING

Date of Test : 13/11/2026

ANSWER KEY ➤

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

DETAILED EXPLANATIONS

1. (b)

Linear interpolation,

^{o}x	^{o}y
50	100
200	50
x	y

$$\frac{x-200}{50-200} = \frac{y-50}{100-50}$$

For $x = y$

$$\frac{x-200}{-150} = \frac{x-50}{50}$$

$$\Rightarrow \qquad x = 87.5^{\circ}x$$

2. (c)

An intensive property is a property of matter that depends only on the type of matter in a sample and independent of mass of matter. Example : Temperature, density, solubility, conductivity, viscosity, pressure, etc.

3. (d)

$$c_{\text{poly}} = c_v\left(\frac{\gamma - n}{1-n}\right)$$

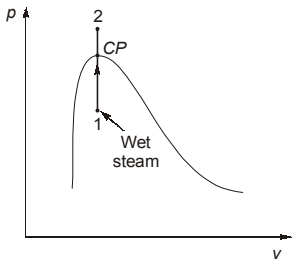
4. (b)

For irreversible system, Clausius inequality

$$\oint \frac{\delta Q}{T} < 0$$

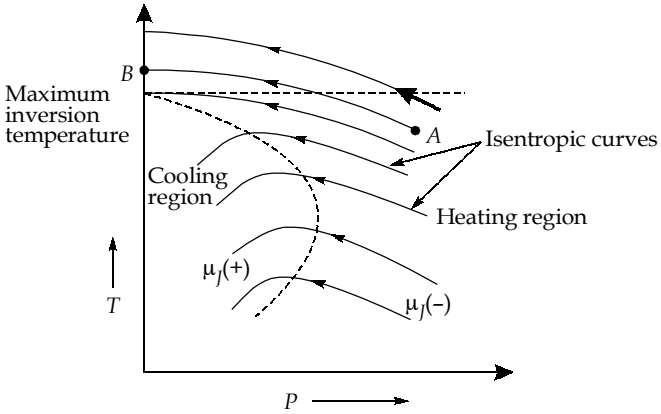
and refrigerator $\oint \delta Q < 0$.

5. (a)



Constant volume heat addition process passing through critical point.

6. (c)



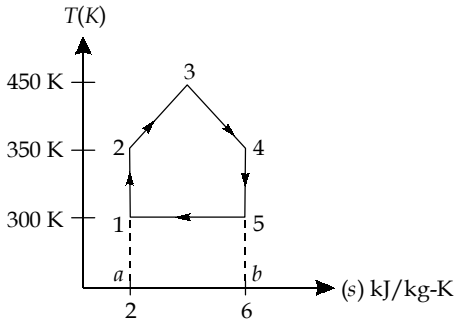
As gas is throttled above maximum inversion temperature (curve AB and above) then the temperature of gas keeps on increasing.

7. (b)

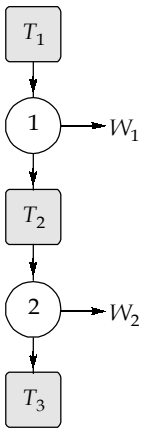
$$\eta = \frac{\text{Work}}{Q_{\text{supply}}} = \frac{ar(1-2-3-4-5-1)}{ar(a-2-3-4-b-a)}$$

$$= \frac{\frac{1}{2}\times 100\times 4 + 50\times 4}{\frac{1}{2}\times 100\times 4 + 350\times 4}$$

$$= \frac{400}{1600} = \frac{1}{4} = 25\%$$



8. (d)



For series combination with same efficiency,

$$T_2^2 = T_1 \times T_3$$

$$(327 + 273)^2 = T_1 \times 500$$

$$T_1 = \frac{600^2}{500} = 720 \text{ K}$$

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9. (a)

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

10. (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.

11. (c)

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

Gas constant: $R = c_p - c_v$

$= 1 - 0.75 = 0.25$ kJ/kgK

Applying equation of state in terms of density,

$$p = \rho R T$$
$$100 = \rho \times 0.25 \times 300$$
$$1 = 0.75\ \rho$$

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

12. (a)

Volume of the balloon is $= m[v_f + xv_{fg}]$

$= 2[0.001053 + 0.85\ (1.1594 - 0.001053)]$

$= 1.971 \text{ m}^3$

$$\frac{\pi}{6}D^3 = 1.971$$
$$D = 1.55 \text{ m}$$

13. (c)

Mixture of gas,

$$\text{Oxygen } (O_2) = 0.1 \text{ kmol}$$
$$\text{Nitrogen } (N_2) = 0.1 \text{ kmol}$$
$$\text{Methane } (CH_4) = 0.8 \text{ kmol}$$

Molar mass, $O_2 = 32$ kg/kmol

$N_2 = 28$ kg/kmol

$CH_4 = 16$ kg/kmol

Mass of O_2 = Mole × Molar mass

$= 0.1 \times 32 = 3.2$ kg

Mass of N_2 = Mole × Molar mass

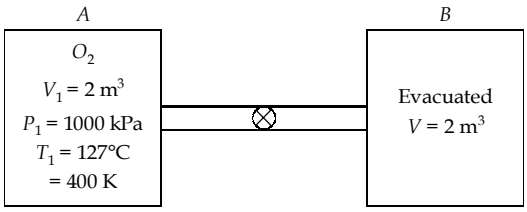
$= 0.1 \times 28 = 2.8$ kg

Mass of CH_4 = Mole × Molar mass

$= 0.8 \times 16 = 12.8$ kg

$$\text{Mass fraction of } N_2 = \frac{m_{N_2}}{m_{O_2} + m_{N_2} + m_{CH_4}} = \left(\frac{2.8}{3.2 + 2.8 + 12.8}\right) = 0.148$$

14. (d)



Taking chamber A and chamber B together as a system.

$$dQ = dU + dW$$

Since $dQ = dW = 0$

$\Rightarrow dU = 0$

No change in internal energy $\Rightarrow$ No change in temperature of air.

Ideal gas equation, T = Constant

$$\Rightarrow P_1V_1 = P_2V_2$$

$$\Rightarrow P_2 = \frac{P_1V_1}{V_2} = (1000)\times\frac{2}{4} = 500\ \text{kPa}$$

15. (d)

Given: $t = ax^2 + b$

At $x = 5$ cm, $t = 0°$,

$$\Rightarrow 0 = a \times 25 + b$$

$$\Rightarrow -25a = +b \quad \text{... (i)}$$

At $x = 20$ cm, $t = 100°$,

$$\Rightarrow 100 = 400a + b$$

From equation (i), $100 = 400a - 25a$

$$a = \frac{100}{375} = \frac{4}{15}$$

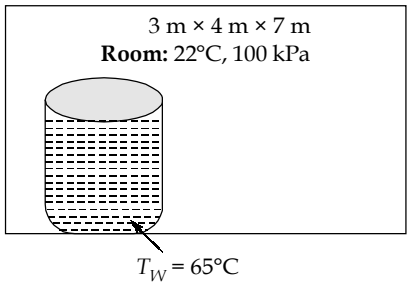
$$\Rightarrow b = -25 \times \frac{4}{15} = -\frac{20}{3}$$

At $x = 15$, $t = \frac{4}{15}\times 15^2 + \left(-\frac{20}{3}\right) = 53.33°C$

16. (a)

Mass of air in the room,

$$m_{air} = \frac{P_1V}{RT_1} = \frac{(100)\times 3\times 4\times 7}{0.287\times 295} = 99.214\ \text{kg}$$



By energy balance:

Heat lost by water = Heat gain by air

$$1000 \times 4.18 \times (65 - T_f) = 99.21 \times 0.718\ (T_f - 22)$$

$$58.763(65 - T_f) = T_f - 22$$

$$\Rightarrow T_f = 64.28°C$$

Now, $X_{destroyed} = T_oS_{gen}$

where, $S_{gen} = (\Delta S)_{water} + (\Delta S)_{air}$

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$$= mc_w \ln\left(\frac{T_f}{T_w}\right) + m_{air} \times c_v \times \ln\left(\frac{T_f}{T_q}\right)$$

$$= 1000 \times 4.186 \ln\left(\frac{273+64.28}{273+65}\right) + 99.214 \times 0.718 \ln\left(\frac{273+64.28}{273+22}\right)$$

$$= 0.6147 \text{ kJ/K}$$

So, $X_{destruction} = 283 \times 0.6147 = 173.98 \text{ kJ}$

17. (c)

Mass balance: $m_i - m_e = m_2 - m_1$

$$m_e = m_1 - m_2$$

Energy balance: $(\Delta E)_{system} = E_{in} - E_{out}$

$$E_{in} = m_i h_i + Q_i + W_i = W_i \qquad (Q_i = 0,\ m_i h_i = 0)$$

$$E_{out} = m_e h_e + Q_e + W_e = m_e h_e \qquad (Q_e = 0,\ W_e = 0)$$

$$W_i - m_e h_e = m_2 u_2 - m_1 u_1$$

$$W_i - (m_1 - m_2) h_e = m_2 u_2 - m_1 u_1$$

$$m_1 = \frac{P_1 V_1}{RT_1} = \frac{500 \times 1.7}{0.287 \times 323} = 9.169 \text{ kg}$$

$$m_2 = \frac{P_2 V_2}{RT_2} = \frac{200 \times 1.7}{0.287 \times 323} = 3.667 \text{ kg}$$

$$u_2 = u_1 = c_v T$$

$$W_i = (m_1 - m_2) h_e + m_2 u_2 - m_1 u_1$$

$$= 5.502 \times 1.005 \times 323 + (-5.502) \times 0.718 \times 323$$

$$= 510.04 \text{ kJ}$$

18. (d)

$$W = (\Delta h)_{air} + (\Delta h)_{water} + Q$$

$$90 = 30 + 40 + Q$$

$$Q = 20 \text{ kJ/kg}$$

19. (a)

Work potential = Exergy (non-flow) = $\phi_1 - \phi_0$

$$= \left[(u_1 - u_0) + P_0(V_1 - V_0) - T_0(S_1 - S_0)\right]$$

Here, $u_1 = u_0$ as $T_1 = T_0$

and, $P_0(V_1 - V_0) = P_0\left(\frac{RT_1}{P_1} - \frac{RT_0}{P_0}\right) = RT_0\left(\frac{P_0}{P_1} - 1\right)$

and, $T_0(S_1 - S_0) = T_0\left(c_p \ln\left(\frac{T_1}{T_0}\right) - R\ln\left(\frac{P_1}{P_0}\right)\right) = -RT_0 \ln\left(\frac{P_1}{P_0}\right)$

$\Rightarrow \quad \phi = RT_0\left[\ln\left(\frac{P_1}{P_0}\right) + \frac{P_0}{P_1} - 1\right]$

20. (d)

$T_0 = 25 + 273 = 298$, $T_1 = 50°C = 273 + 50 = 323$ K, $P_1 = 800$ kPa, $m = 0.5$ kg/s, $P_2 = 200$ kPa

Assuming air as ideal gas and for throttling,

$$h_1 = h_2$$

$$\Rightarrow \quad T_1 = T_2$$

So, $$\Delta S = c_p \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}$$

$$= 0 - 0.287\ln\left(\frac{1}{4}\right) = 0.287\ln 4 = 0.287\times 2\times 0.693$$

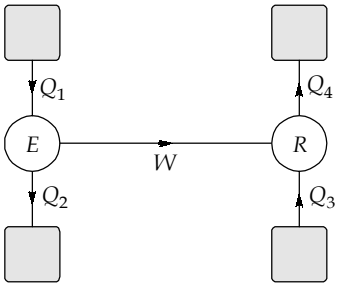
Power waisted, $I = mT_0\Delta S = 0.5 \times 298 \times 0.287 \times 2 \times 0.693$

$= 59.28$ kW

21. (c)

- $$du = c_v dT + \left[T\left(\frac{\partial P}{dT}\right)_v - P\right]dv$$
- $$dh = c_P dT + \left[v - T\left(\frac{dv}{dT}\right)_P\right]dP$$
- $$c_p - c_v = -T\left(\frac{\partial v}{\partial T}\right)_P^2\left(\frac{\partial v}{\partial T}\right)_T = \frac{Tv\beta^2}{k_t}$$
- $$\mu = \left(\frac{\partial T}{\partial P}\right)_h = \frac{1}{c_p}\left[T\left(\frac{\partial v}{\partial T}\right)_P - v\right]$$

22. (a)



Given: $$\eta_E = 0.5$$

Also $$Q_1 = \frac{1}{2}(Q_2 + Q_4)$$

$$W = \eta Q_1 = 0.5Q_1$$

$$\Rightarrow \quad Q_2 = Q_1 - W = 0.5Q_1$$

$$\Rightarrow \quad Q_4 = 2Q_1 - Q_2 = 1.5Q_1$$

$$(\text{COP})_R = \frac{Q_3}{Q_4 - Q_3} = \frac{Q_4 - W}{W}$$

$$= \frac{Q_4}{W} - 1 = \frac{1.5Q_1}{0.5Q_1} - 1 = 3 - 1 = 2$$

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23. (c)

Applying steady flow energy equation,

$$m\left(h_1+\frac{v_1^2}{2}+gz_1\right)+Q = m\left(h_2+\frac{v_2^2}{2}+gz_2\right)+W$$

For adiabatic flow, $Q = 0$,

$$\Rightarrow \quad m\left(h_1+\frac{v_1^2}{2000}+\frac{gz_1}{1000}\right) = m\left(h_2+\frac{v_2^2}{2000}+\frac{gz_2}{1000}\right)+W$$

$$\Rightarrow m\left(h_1-h_2+\frac{v_1^2-v_2^2}{2000}+\frac{g(z_1-z_2)}{1000}\right) = 70000$$

$$\Rightarrow \quad m\left(3700-2000+\frac{150^2-150^2}{2000}+\frac{9.81}{1000}(15-2)\right) = 70000$$

$$\Rightarrow \qquad m = 41.2 \text{ kg/s}$$

24. (d)

Given: $V_1 = 0.05\ \text{m}^3$

Now, enclosed volume at final state is

$$V_2 = 2V_1 = 0.1\ \text{m}^3$$

$\therefore$ Displacement of piston, $x = \dfrac{\Delta V}{A} = \dfrac{0.05}{0.25} = 0.2\ \text{m}$

Force applied by linear spring at final state,

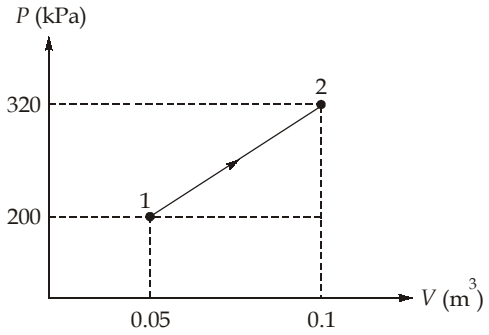
$$F_{\text{spring}} = kx = 150 \times 0.2 = 30\ \text{kN}$$

Additional pressure applied by spring,

$$P = \frac{F_{\text{spring}}}{A} = \frac{30}{0.25} = 120\ \text{kPa}$$

Without the spring, pressure of gas would remain constant at 200 kPa but under the effect of spring, pressure rises linearly from 200 kPa to (200 + 120) = 320 kPa.

Now, total work done by gas = Area under the process (1-2)



$$W = \text{Area} = \left(\frac{200+320}{2}\right)(0.1-0.05)\,\text{kJ} = 13\ \text{kJ}$$

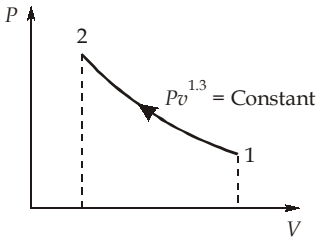
25. (b)

The change in availability of closed system is not equal to change in Helmholtz function at given room temperature.

The change in availability of closed system

$\phi_1 - \phi_2 = (u_1 + P_oV_1 - T_oS_1) - (u_2 + P_oV_2 - T_oS_2)$

26. (a)



Mass = 1 kg of ideal gas

Initial, P_1 = 100 kPa

T_1 = 250 K

Final, T_2 = 500 K

R = 287 J/kgK

γ = 1.4

$$W_{1\text{-}2} = -\left(\frac{P_2V_2 - P_1V_1}{n-1}\right)$$

$$= \frac{-mR(T_2 - T_1)}{n-1}$$

$U_{1\text{-}2} = U_2 - U_1 = mc_v(T_2 - T_1)$

$Q_{1\text{-}2} = U_{1\text{-}2} + W_{1\text{-}2}$

$$Q_{1\text{-}2} = 1 \times 0.718(500 - 250) - \frac{1 \times 0.287(500 - 250)}{1.3 - 1}$$

$Q_{1\text{-}2}$ = –59.666 kJ

$Q_{1\text{-}2}$ = 59.666 kJ (Heat transfer from piston cylinder to its surrounding)

Alternatively,

$$Q_{1\text{-}2} = \frac{\gamma - n}{\gamma - 1} \times \left(\frac{P_1V_1 - P_2V_2}{n-1}\right) = \frac{\gamma - n}{\gamma - 1} \times \frac{m \times R \times (T_1 - T_2)}{n-1}$$

$$= \frac{1.4 - 1.3}{1.4 - 1} \times \frac{1 \times 0.287 \times (250 - 500)}{1.3 - 1}$$

$Q_{1\text{-}2}$ = –59.666 kJ

$Q_{1\text{-}2}$ = 59.666 kJ (Heat transfer from piston cylinder to its surrounding)

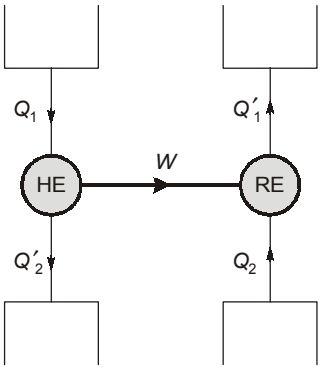
27. (b)

Given: P_C = 20 kPa; V_C = 0.002 m^3; T_C = 300 K

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

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28. (d)



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

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

Multiplying equation (1) and (2)

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

$$\Rightarrow \quad Q_1 = \frac{Q_2}{1.5} = \frac{1000}{1.5} \text{ kJ} = 666.67 \text{ kJ} \qquad (\text{for } Q_2 = 1 \text{ MJ} = 1000 \text{ kJ})$$

29. (c)

Extent of irreversibility of any process is determined by the entropy increase of the universe.

30. (a)

Given; $P = 200 \text{ kN/m}^2$; $W_1 = -150$ kJ; $Q = 50$ kJ

We know, $H = U + PV$

$H_1 = U_1 + P_1V_1$

$H_2 = U_2 + P_2V_2$

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

Work done by the system,

$W_2 = P(V_2 - V_1) = 200 \times (5 - 2) = 600$ kJ

From 1st law of thermodynamics,

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

$\Delta U = \Delta Q - \Delta W = 50 - (-150 + 600) = 50 - 450 = -400$ kJ

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

$\therefore$ $\Delta H = -400 + 200\ (5 - 2) = -400 + 600 = 200$ kJ

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