ESE GATE

State Engg. Exams

MADE EASY Workbook 2026

Detailed Explanations of Try Yourself *Questions*

Mechanical Engineering

Thermodynamics

MADE EASY PUBLICATIONS

1 Basic Concepts and Zeroth Law of Thermodynamics

Detailed Explanation of Try Yourself Questions

T1 : Solution (a)

0°C__________5°C
t°C__________52°C
100°C__________99°C

$$\frac{0-t}{0-100} = \frac{5-52}{5-99}$$

$$t = 50°C$$

$$t = 50 \times \frac{9}{5} + 32 = 122°F$$

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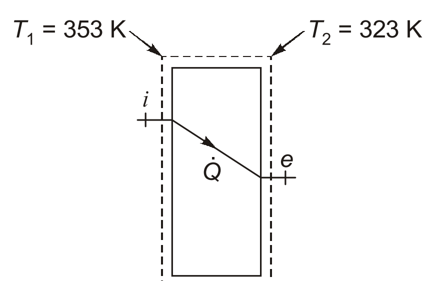
2 Energy Interactions (Heat & Work)

Detailed Explanation of Try Yourself Questions

T1 : Solution



$$\dot{Q} = KA\frac{dT}{dx}$$

$$\dot{Q} = KA\frac{dT}{dx}$$

$$4500 = 15 \times 1 \times \frac{(353 - T_2)}{0.1}$$

$$30 = 353 - T_2$$

$$T_2 = 323 \text{ K}$$

$$\left(\frac{ds}{dt}\right)^{\!\!\not{}\,0}_{\text{C.V.}} = \dot{S}_i + \dot{S}_{\text{gen}} - \dot{S}_e$$

$$\dot{S}_{\text{gen}} = \dot{S}_e - \dot{S}_i = \frac{\dot{Q}}{T_e} - \frac{\dot{Q}}{T_i} = \frac{4500}{323} - \frac{4500}{353}$$

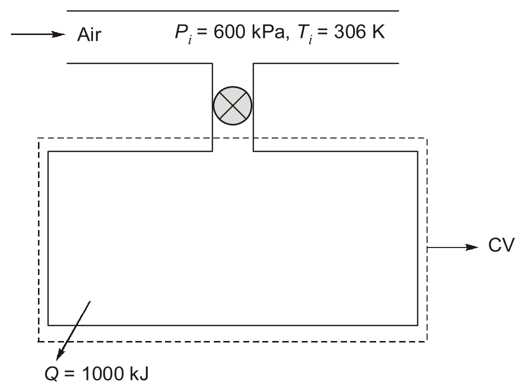
$$= 1.184 \text{ W/k.m}^2$$

T2 : Solution (395.388)

Here, i = Inlet, e = Exit,

Initial condition of CV ⇒ 1

Final condition of CV ⇒ 2



From conservation of mass:

$$m_2 - \cancel{m_1}^{0} = m_i - \cancel{m_e}^{0}$$

$$m_2 = m_e$$

Conservation of energy:

$$U_2 - \cancel{U_1}^{0} = m_i h_i + Q - \cancel{m_e h_e}^{0} - \cancel{W_{CV}}^{0}$$

$$m_2 u_2 = m_2 \times C_P T_i + (-1000)$$

[∵ $u_2 = C_V T_2$ and $m_i = m_2$]

$$m_2 C_V T_2 = m_2 C_V T_i - 1000$$

$$\frac{P_2 V}{RT_2} \times C_V \times T_2 = \frac{P_2 V}{RT_2} \times C_V \times T_i - 1000$$

[By Ideal gas equation]

$$\frac{600 \times 8}{0.287} \times 0.718 = \frac{600 \times 8}{0.287 \times T_2} \times 1.005 \times 306 - 1000$$

$$\Rightarrow \quad T_2 = 395.388 \text{ K}$$

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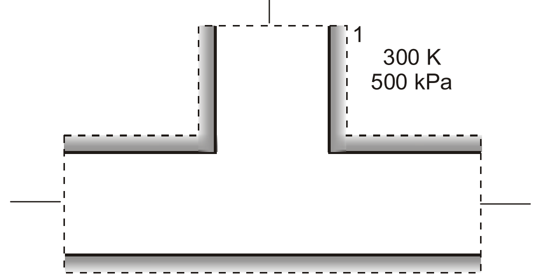
3 First Law of Thermodynamics

Detailed Explanation of Try Yourself Questions

T1 : Solution



$$\left(\frac{dS}{dt}\right)_{C.V.} = \dot{S}_i + \dot{S}_{gen} - \dot{S}_e$$

$$\because \quad \left(\frac{dS}{dt}\right)_{C.V.} = 0 \text{ [Steady state]}$$

$$\dot{S}_{gen} = \dot{S}_e - \dot{S}_i$$

$$= \underset{\downarrow \atop 3}{\dot{m}_2} s_2 + \underset{\downarrow \atop 2}{\dot{m}_3} s_3 - \underset{\downarrow \atop 5}{\dot{m}_1} s_1$$

$$= 3(s_2 - s_1) + 2(s_3 - s_1)$$

$$= 3 \times 0.587 + 2(0.237)$$

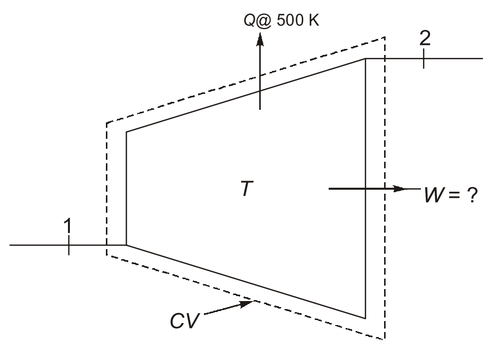
$$= 2.235 \text{ kW/K} \simeq 2.2 \text{ kW/K}$$

T2 : Solution

For reversible process

$$\dot{S}_{gen} = 0$$

$$\left(\frac{dS}{dt}\right)_{CV}^{0\,(\text{Steady state})} = \dot{S}_i + \dot{S}_{gen}^{0\,(\text{Reversible})} - \dot{S}_e$$



$$0 = \dot{m}s_1 - \left\{\dot{m}s_2 + \frac{\dot{Q}}{500}\right\}$$

$$0 = 500 \times \{6.5 - 6.3\} - \frac{\dot{Q}}{500}$$

$$\dot{Q} = 50000 \text{ kW}$$

$$\dot{Q} = 50 \text{ MW}$$

Conservation of energy:

$$\dot{E}_{in} = \dot{E}_{exit}$$

$$\dot{m}h_1 = \dot{m}h_2 + \dot{Q} + \dot{W}$$

$$\dot{m}(h_1 - h_2) = \dot{Q} + \dot{W}$$

500 (3500 – 2500) = 50000 + $\dot{W}$

$$\dot{W} = 450000 \text{ kW}$$

$$\dot{W} = 450 \text{ MW}$$

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4 Second Law of Thermodynamics

Detailed Explanation of Try Yourself Questions

T1 : Solution

$$T_L = 2 + 273 = 275\text{K}$$
$$T_H = 300\,\text{K}$$
$$(\text{COP})_{\text{ideal}} = \frac{T_L}{T_H - T_L} = \frac{275}{300 - 275} = 11$$
$$(\text{COP})_{\text{actual}} = 20 \text{ percent of } (\text{COP})_{\text{ideal}}$$
$$= 0.2 \times 11 = 2.2$$

Let the electricity consumed per day is x

x × (Number of days) × (Rate of electricity) = Monthly bill

$$\Rightarrow \quad x \times 30 \times 3 = 200$$
$$\Rightarrow \quad x = 2.22 \text{ kWh} \simeq 8000 \text{ kJ}$$
$$Q_{\text{in}} \text{ per day} = x \times (\text{COP})_{\text{actual}} = 17600 \text{ kJ}$$
$$n \times 400 = 17600$$
$$\Rightarrow \quad n = \frac{17600}{400} = 44$$

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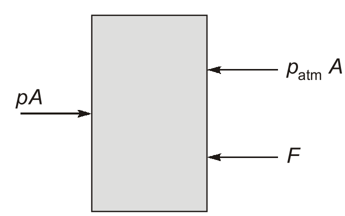
5 Entropy, Availability and Irreversibility

Detailed Explanation of Try Yourself Questions

T1 : Solution

The initial and final pressure of the air are calculated from a free-body diagram of the piston, as follows



$$pA = p_{atm}A + F$$

$$pA = p_{atm}A + kx$$

$$pA = p_{atm}A + \frac{k(V_2 - V_1)}{A}$$

or
$$p = p_{atm} + \frac{k(V_2 - V_1)}{A^2}$$

Initially, spring force, $F = 0$

$\therefore$ $p_1 = p_{atm} = 100$ kPa

Final pressure,
$$p_2 = p_{atm} + \frac{k(V_2 - V_1)}{A^2} = 100 + \frac{10 \times (0.003 - 0.002)}{(0.02)^2}$$

$$= 100 + 25 = 125 \text{ kPa}$$

$$s_2 - s_1 = c_v \log_e \frac{p_2}{p_1} + c_p \log_e \frac{V_2}{V_1}$$

$$= 0.718 \log_e \frac{125}{100} + 1.005 \log_e \frac{0.003}{0.002}$$

$$= 0.16017 + 0.40749$$

$$= 0.56766 \text{ kJ/kgK}$$

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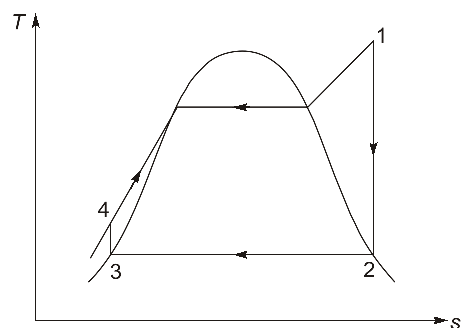
6 Properties of Pure Substance

Detailed Explanation of Try Yourself Questions

T1 : Solution (b)

For minimum possible dryness fraction at the exit of the adiabatic turbine, the process must be reversible



$$s_1 = s_2$$

$$6.9362 = s_f + x_2\, s_{fg} \text{ at 50 kPa}$$

$$6.9362 = 1.091 + x_2\,(7.5939 - 1.091)$$

$$x_2 = 0.899 \text{ or } 89.9\%$$

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7 Thermodynamic Relations and Clapeyron Equation

Detailed Explanation of Try Yourself Questions

T1 : Solution (b)

$$\beta = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_P$$

$$5 \times 10^{-5} = \frac{1}{0.000114}\left(\frac{\partial V}{\partial T}\right)_P$$

$$\left(\frac{\partial V}{\partial T}\right)_P = 570 \times 10^{-11} \text{ m}^3/\text{kgK}$$

Now,

$$k = -\frac{1}{v}\left(\frac{\partial V}{\partial P}\right)_T$$

$$8.6 \times 10^{-12} = -\frac{1}{0.000114}\left(\frac{\partial V}{\partial T}\right)_T$$

$$\left(\frac{\partial V}{\partial P}\right)_T = -980 \times 10^{-18} \text{ m}^3/\text{kgPa}$$

$$C_P - C_V = -T\left(\frac{\partial P}{\partial V}\right)_T\left[\left(\frac{\partial V}{\partial T}\right)_P\right]^2 - (273+25)\left(\frac{1}{-980 \times 10^{-18}}\right)(570 \times 10^{-11})^2$$

$$= 9.8755 \text{ J/kgK}$$

$$C_P = \frac{\gamma}{\gamma - 1}(C_P - C_V) = \frac{1.024}{1.024 - 1} \times 9.8755$$

$$= 421.35 \text{ J/kgK}$$

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