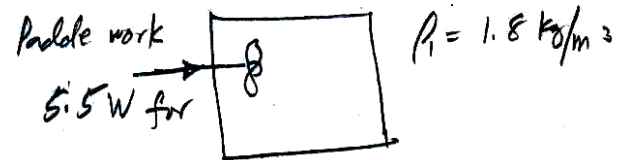


Answer Key

Problem Set



a)

Using NFEE

$$\dot{Q} = \Delta U + W_{\text{NF}}$$

$$0 = m \Delta U + W_{\text{NF}}$$

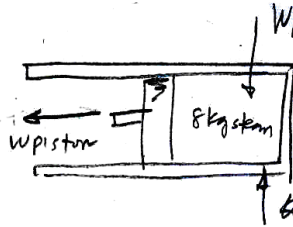
$$\rho = \frac{m}{V}$$

$$1.8 \text{ kg/m}^3 = \frac{m}{0.5 \text{ m}^3}$$

$$m = 0.9 \text{ kg}$$

$$-(0.9 \text{ kg}) \Delta U = -\left(5.5 \frac{\text{J}}{\text{s}}\right) \left(\frac{60 \text{ s}}{1 \text{ min}}\right) (30 \text{ min}) \left(\frac{1 \text{ kJ}}{1000 \text{ J}}\right)$$

$$\Delta U = 11 \text{ kJ/kg}$$



$W_{\text{paddle}} = 20 \text{ kJ}$
 $W_{\text{piston}} = ?$
 8 kg steam
 $Q = 75 \text{ kJ}$
 $T_{\text{in}} = \text{const}$

$U_1 = 2710.0 \text{ kJ/kg}$
 $U_2 = 2660.5 \text{ kJ/kg}$

$$U_1 + W_{\text{paddle}} + Q = W_{\text{piston}} + U_2$$

$$W_{\text{piston}} = W_{\text{paddle}} + Q - \Delta U$$

$$= 20 \text{ kJ} + 75 - (8 \text{ kg})(2660.5 - 2710) \text{ kJ/kg}$$

$W_{\text{piston}} = 491 \text{ kJ}$

$$PV = C \quad P_1 = 250 \text{ kPa} \quad P_2 = 120 \text{ kPa}$$

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

$$W_{if} = \int P dV \quad PV = C$$

$$P = \frac{C}{V}$$

$$= C \int_{V_1}^{V_2} \frac{dV}{V}$$

$$= C \ln\left(\frac{V_2}{V_1}\right) = P_1 V_1 \ln\left(\frac{V_2}{V_1}\right)$$

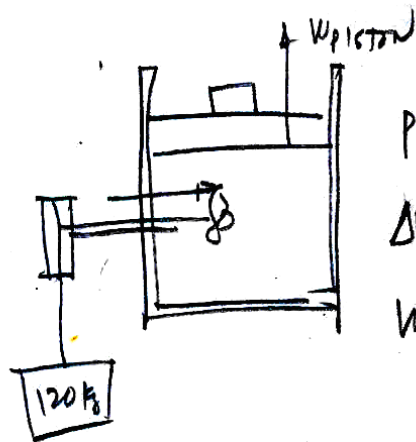
$$P_1 V_1 = P_2 V_2$$

$$(250 \text{ kPa})(2 \text{ m}^3) = (120 \text{ kPa}) V_2$$

$$V_2 = 4.1667 \text{ m}^3$$

$$= (250 \text{ kPa})(2 \text{ m}^3) \ln\left(\frac{4.1667 \text{ m}^3}{2 \text{ m}^3}\right)$$

$$W_{if} = 366.9886 \text{ kJ}$$



$$P_1 = P_2 = 100 \text{ kPa}$$

$$\Delta V = 0.0025 \text{ m}^3$$

$$W_{\text{net}} = ?$$

$$W_{\text{net}} = -W_{\text{paddle}} + W_{\text{piston}}$$

$$W_{\text{paddle}} = -F s = (120 \text{ kg}) \left(\frac{9.81 \text{ m/s}^2}{1 \frac{\text{kg} \cdot \text{m}}{\text{N} \cdot \text{s}^2}} \right) (4 \text{ m})$$

$$= -4706.8 \text{ J}$$

$$= -4.7088 \text{ kJ} \quad \text{work done on the system}$$

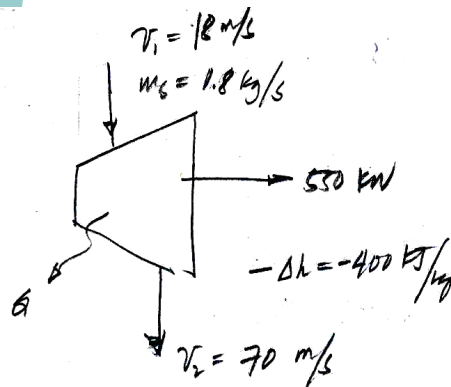
$$W_{\text{piston}} = \int_1^2 \vec{P} dV = P(V_2 - V_1)$$

$$= (100 \text{ kPa})(0.0025 \text{ m}^3)$$

$$= 0.25 \text{ kJ} \quad \text{work going out of the system}$$

$$W_{\text{NET}} = (-4.7088 + 0.25) \text{ kJ}$$

$$W_{\text{NET}} = -4.4588 \text{ kJ}$$



$$; \Delta z = (z_2 - z_1)$$

$$\Delta z = -900 \text{ mm}$$

$$[E_{in} = E_{out}]$$

$$PE_1 + KE_1 + U_1 + W_{f1} = W_{sf} + Q + PE_2 + KE_2 + U_2 + W_{f2}$$

$$0 = W_{sf} + Q + \Delta PE + \Delta KE + (\Delta U + \Delta W_f)$$

$$-Q = W_{sf} + \Delta PE + \Delta KE + \Delta H$$

$$\Delta PE = m \left(\frac{g_0}{g_c} \right) \Delta z = \left(1.8 \frac{\text{kg}}{\text{s}} \right) \left(\frac{9.81 \frac{\text{m}}{\text{s}^2}}{1 \frac{\text{kg} \cdot \text{m}}{\text{N} \cdot \text{s}^2}} \right) (-0.90 \text{ m})$$

$$\Delta PE = -15.8972 \frac{\text{N} \cdot \text{m}}{\text{s}} \text{ or } \text{W}$$

$$= -0.01589 \text{ kW}$$

$$\Delta KE = \frac{1}{2} \frac{m}{g_c} (v_2^2 - v_1^2) = \frac{(1.8 \frac{\text{kg}}{\text{s}})}{2 \left(1 \frac{\text{kg} \cdot \text{m}}{\text{N} \cdot \text{s}^2} \right)} (70^2 - 18^2) \frac{\text{m}^2}{\text{s}^2}$$

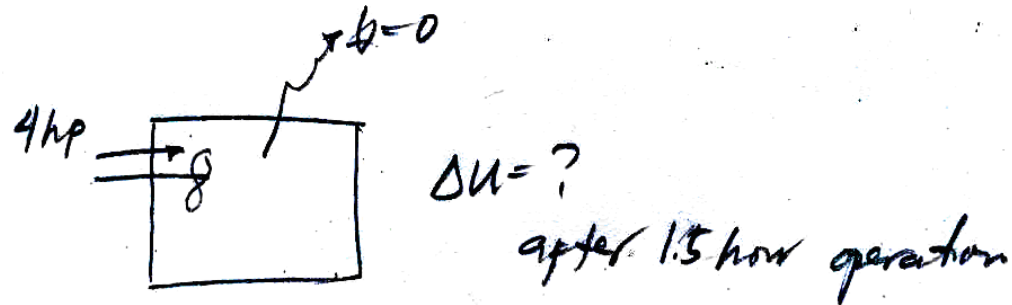
$$\Delta KE = 4118.4 \text{ W}$$

$$= 4.1184 \text{ kW}$$

$$Q = 550 \text{ kW} - 0.01589 \text{ kW} + 4.1184 \text{ kW} + (1.8 \frac{\text{kg}}{\text{s}}) (-400 \frac{\text{kJ}}{\text{kg}})$$

$$Q = -165.8974$$

$$Q = 165.8974 \text{ kW} \text{ "heat going out of the system"}$$



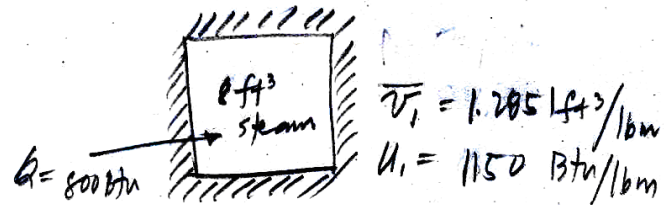
$$[E_{in} = \text{work}]$$

$$U_1 + W_{in} = \cancel{Q} + U_2$$

$$W_{in} = (U_2 - U_1)$$

$$\Delta U = (4 \text{ hp})(1.5 \text{ hr}) \left(\frac{746 \text{ W}}{1 \text{ hp}} \right) \left(\frac{3600 \text{ s}}{1 \text{ hr}} \right)$$

$$\Delta U = 1.6114 \times 10^7 \text{ J}$$



$$[E_{in} = E_{out}]$$

$$u_1 + Q = \cancel{W_{net}} + u_2$$

$$Q = \Delta U = m(u_2 - u_1)$$

$$m = \frac{V}{\bar{v}} = \frac{8 \text{ ft}^3}{1.205 \text{ ft}^3/\text{lbm}}$$

$$m = 6.2252 \text{ lbm}$$

$$800 \text{ Btu} = 6.2252 \text{ lbm} (u_2 - 1150) \text{ Btu/lbm}$$

$$u_2 = 1278.5099 \text{ Btu/lbm}$$

$$m = 2 \text{ kg}$$

$$T_1 = 303 \text{ K}$$

$$V = 3.2 \text{ m}^3$$

$$P_1 = 150 \text{ kPa}$$

rigid container

$$P_1 V_1 = m R T_1$$

$$(150 \text{ kPa})(3.2 \text{ m}^3) = (2 \text{ kg}) R (303 \text{ K})$$

$$R = 0.7921 \text{ kJ/kg-K}$$

Hydrogen

$$P_1 = 100 \text{ kPa}$$

$$t_1 = 20^\circ\text{C}$$

$$m_{\text{added}} = 1.5 \text{ kgs}$$

$$t_2 = 30^\circ\text{C}$$

$$P_2 = 250 \text{ kPa}$$

$$R_{H_2} = 4.125 \text{ kJ/kg}\cdot\text{K}$$

a) Value of the tank

$$P_1 V_1 = m R T_1$$

$$(100 \text{ kPa}) V_1 = m (4.125 \text{ kJ/kg}\cdot\text{K}) (20 + 273) \text{ K}$$

$$V_1 = 12.0863 \text{ m}^3$$

$$\text{for } m_1; V_1 = V_2$$

$$P_2 V_2 = m_2 R T_2$$

$$(250 \text{ kPa}) (12.0863 \text{ m}^3) = (m_1 + 1.5 \text{ kgs}) (4.125 \text{ kJ/kg}\cdot\text{K}) (30 + 273) \text{ K}$$

$$m_1 = 1.0581 \text{ kg}$$

therefore;

$$V_1 = \left(12.0863 \frac{\text{m}^3}{\text{kg}}\right) (1.0581 \text{ kg})$$

$$V_1 = 12.7885 \text{ m}^3$$

b.) final mass;

$$m_2 = m_1 + m_{\text{added}} = 1.0581 \text{ kg} + 1.5 \text{ kg}$$

$$m_2 = 2.5581 \text{ kgs}$$

$$P_1 = 275 \text{ kPa}_g$$
$$t_1 = 20^\circ\text{C}$$

Purstig pressure

$$P_B = 1800 \text{ kPa}_g$$
$$t_B = ?$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$
$$\frac{(275 + 101.325 \text{ kPa}_g)}{(20 + 273) \text{ K}} = \frac{(1800 + 101.325 \text{ kPa}_g)}{T_B}$$

$$T_B = 1520.75 \text{ K}$$

$$t_B = 1247.75^\circ\text{C}$$

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

$$P_1 = 320 \text{ kPa}$$

$$T_1 = 315 \text{ K}$$

$$P_2 = 280 \text{ kPa}$$

$$T_2 = 300 \text{ K}$$

a) mass of Helium leaked out

$$P_1 V_1 = m_1 R T_1$$

$$(320 \text{ kPa} + 101.325 \text{ kPa})(2 \text{ m}^3) = m_1 (2.077 \text{ kJ/kg} \cdot \text{K})(315 \text{ K})$$

$$m_1 = 1.28795 \text{ kg}$$

$$P_2 V_2 = m_2 R T_2$$

$$(280 + 101.325) \text{ kPa} (2 \text{ m}^3) = m_2 (2.077 \text{ kJ/kg} \cdot \text{K})(300 \text{ K})$$

$$m_2 = 1.22396 \text{ kg}$$

(b.) Hence the mass leaked out

$$m_{\text{leak}} = 0.06399 \text{ kg}$$

$$V_A = 90 \text{ L}$$

$$P_A = 3500 \text{ kPa}$$

$$t_A = 60^\circ \text{C}$$

$$V_B = ?$$

$$P_B = 200 \text{ kPa}$$

$$t_B = 20^\circ \text{C}$$

$$P_m = 1800 \text{ kPa}$$

$$t_m = 32^\circ \text{C}$$

$$V_m = V_A + V_B$$

$$V_m = 0.09 \text{ m}^3 + V_B$$

$$\left| \frac{PV}{T} \right|_m = \left| \frac{PV}{T} \right|_A + \left| \frac{PV}{T} \right|_B$$

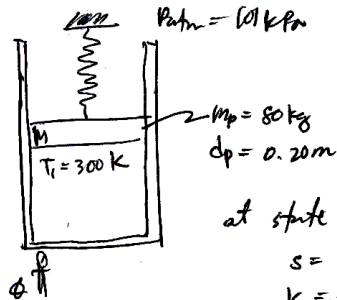
$$\frac{(1800 \text{ kPa})(V_m)}{305 \text{ K}} = \frac{(3500 \text{ kPa})(0.09 \text{ m}^3)}{333 \text{ K}} + \frac{(200 \text{ kPa})(V_B)}{293 \text{ K}}$$

$$5.9016 V_m = 0.9459 + 0.6026 V_B$$

$$V_B = 0.07947 \text{ m}^3$$

$$V_B = 79.47 \text{ L}$$

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at state 2, when heat is added
 $s = 0.18 \text{ m}$
 $k = 30 \text{ kN/m}$

a) initial pressure of air, the spring just touches the piston

$$P_1 = P_{atm} + \frac{W}{A} = 101 \text{ kPa} + \frac{(80 \text{ kg}) \left(\frac{9.81 \text{ m/s}^2}{1 \text{ kg} \cdot \text{m} / \text{N} \cdot \text{s}^2} \right) \left(\frac{1 \text{ kN}}{1000 \text{ N}} \right)}{\frac{\pi (0.20 \text{ m})^2}{4}}$$

$$P_1 = 125.9809 \text{ kPa}$$

(b.) Final temperature of air

$$P_2 = P_1 + \frac{k s}{A} = 125.9809 \text{ kPa} + \frac{(30 \text{ kN/m}) (0.18 \text{ m})}{\frac{\pi (0.20 \text{ m})^2}{4}}$$

$$P_2 = 297.8682 \text{ kPa}$$

$$P_2 V_2 = m P T_2$$

$$V_2 = \frac{\pi d^2}{4} (h + 0.18)$$

$$V_1 = \frac{\pi d^2}{4} h$$

for V_1 :

$$P_1 V_1 = m P T_1$$

$$(125.9809 \text{ kPa}) V_1 = (0.1 \text{ kg}) \left(\frac{0.287 \text{ kJ}}{\text{kg} \cdot \text{K}} \right) (300 \text{ K})$$

$$V_1 = 0.06834 \text{ m}^3$$

$$0.06834 \text{ m}^3 = \frac{\pi (0.20 \text{ m})^2}{4} h$$

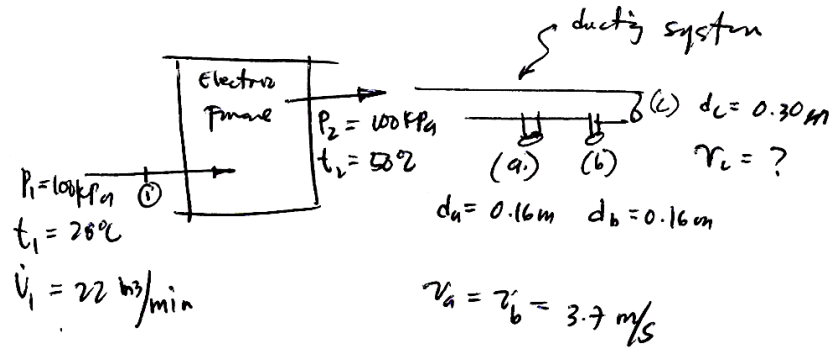
$$h = 2.17545 \text{ m}$$

$$V_2 = \frac{\pi (0.20 \text{ m})^2}{4} (2.17545 \text{ m} + 0.18 \text{ m}) = 0.07399 \text{ m}^3$$

$$(297.8682 \text{ kPa}) (0.07399 \text{ m}^3) = (0.1 \text{ kg}) \left(\frac{0.287 \text{ kJ}}{\text{kg} \cdot \text{K}} \right) T_2$$

$$T_2 = 768. \text{ K}$$

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a) mass flow rate of air exiting the furnace

$$P_1 V_1 = m R T_1$$

$$(100 \text{ kPa}) \left(\frac{22 \text{ m}^3}{60 \text{ s}} \right) = m (0.287 \text{ kJ/kg} \cdot \text{K}) (28 + 273) \text{ K}$$

$$m_i = 0.4244 \text{ kg/s}$$

b) velocity of air at duct c

mass balance

$$m_i = m_a + m_b + m_c$$

$$m_a = m_b$$

$$PV = mRT$$

$$m_a = m_b = \frac{PV}{RT} = \frac{(100 \text{ kPa}) \left[\frac{\pi (0.16 \text{ m})^2}{4} \right] (3.7 \text{ m/s})}{(0.287 \text{ kJ/kg} \cdot \text{K}) (50 + 273) \text{ K}}$$

$$m_a = m_b = 0.08025 \text{ kg/s}$$

hence;

$$0.4244 \text{ kg/s} = 0.08025 \text{ kg/s} + 0.08025 \text{ kg/s} + m_c$$

$$m_c = 0.263899 \text{ kg/s}$$

Solving for Velocity;

$$P_c V_c = m_c R T_c$$

$$(100 \text{ kPa}) V_c = (0.263899 \text{ kg/s}) (0.287 \text{ kJ/kg} \cdot \text{K}) (50 + 273) \text{ K}$$

$$V_c = 0.24964 \text{ m}^3/\text{s}$$

$$V_c = AV$$

$$0.24964 \text{ m}^3/\text{s} = \frac{\pi (0.30 \text{ m})^2}{4} V_c$$

$$V_c = 3.4609 \text{ m/s}$$