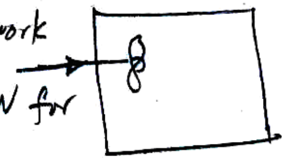
Answer Key

Problem Set

3

Paddle work

5.5 W for



$\rho_1 = 1.8\ kg/m^3$

a) Using NFEE

$$\cancel{Q} = \Delta U + W_{NF}$$

$$0 = m\Delta u + W_{NF}$$

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

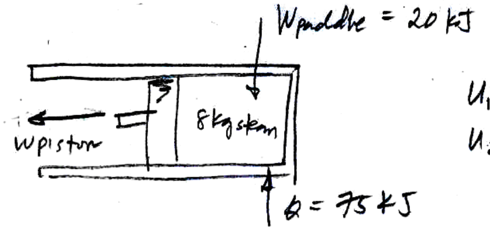
$$1.8\ kg/m^3 = \frac{m}{0.5\ m^3}$$

$$m = 0.9\ kg$$

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

$$\boxed{\Delta u = 11\ kJ/kg}$$

4



$u_1 = 2710.0$ kJ/kg

$u_2 = 2660.5$ kJ/kg

$W_{piston} = ?$

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

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

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

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

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

5

$PV = C \qquad P_1 = 250\ kPa \qquad P_2 = 120\ kPa$

$V_1 = 2m3$

$W_{NF} = \int P\,dV \qquad PV = C$

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

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

$= C \ln\left(\frac{V_2}{V_1}\right) = P_1V_1 \ln\left(\frac{V_2}{V_1}\right)$

$P_1V_1 = P_2V_2$

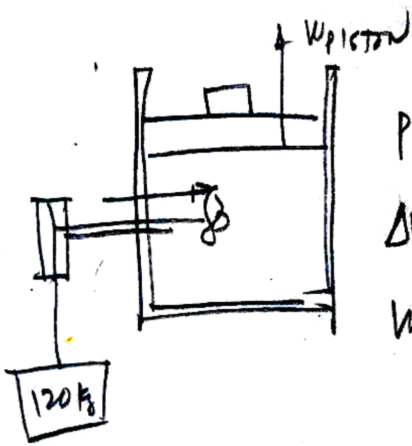
$(250\ kPa)(2m^3) = (120\ kPa)V_2$

$V_2 = 4.1667\ m3$

$= (250\ kPa)(2m3) \ln\left(\frac{4.1667\ m^3}{2m^3}\right)$

$\boxed{W_{NF} = 366.9886\ KJ}$

6



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

$\Delta V = 0.0025\ m^3$

$W_{net} = ?$

$$W_{net} = W_{paddle} + W_{piston}$$

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

$$= -4708.8\ J$$

$$= -4.7088\ kJ$$ work done on the system

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

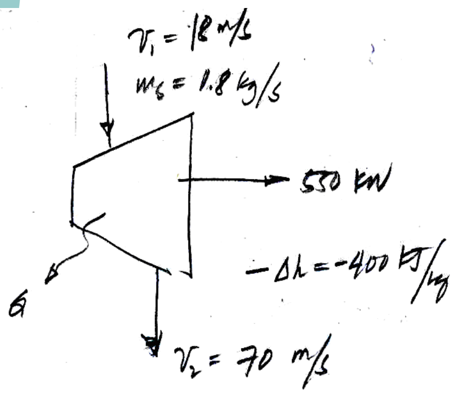
$$= (100\ kPa)(0.0025\ m^3)$$

$$= 0.25\ kJ$$ work going out of the system

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

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

7



$; \Delta z = (\cancel{z_2} - \overset{0}{z_1})$

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

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

$PE_1 + KE_1 + U_1 + W_{f_1} = W_{SF} + Q + PE_2 + KE_2 + U_2 + W_{f_2}$

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

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

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

$\Delta PE = -15.8922 \frac{N\text{-}m}{s}$ or W

$= -0.01589 \text{ kW}$

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

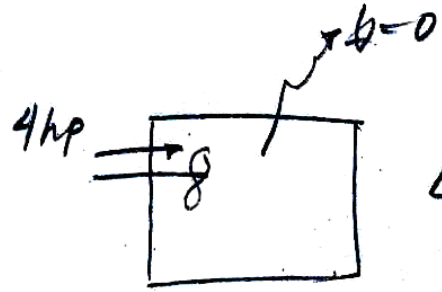
$\Delta KE = 4118.4 \text{ W}$

$= 4.1184 \text{ kW}$

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

$Q = -165.8974$

$\boxed{Q = 165.8974 \text{ kW}}$ "heat going out of the system" exponential LEAP ONLINE REVIEW



$\Delta U = ?$

after 1.5 hour operation

$[E_{IN} = E_{OUT}]$

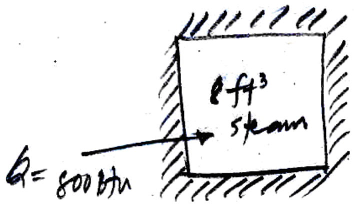
$$U_1 + W_{NF} = \overset{0}{\cancel{Q}} + U_2$$

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

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

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

9



$\bar{v}_1 = 1.2851\ ft^3/lbm$

$u_1 = 1150\ Btu/lbm$

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

$U_1 + Q = \cancel{W_{NF}}^{0} + U_2$

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

$$m = \frac{V}{\bar{v}} = \frac{8\ ft^3}{1.2851\ ft^3/lbm}$$

$$m = 6.2252\ lbm$$

$$800\ Btu = 6.2252\ lbm\,(u_2 - 1150)\ Btu/lbm$$

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

$m = 2\ kgs$ $T_1 = 303\ K$

$V = 3.2\ m^3$ $P_1 = 150\ kPa$

rigid container

$$P_1 V_1 = m R T_1$$

$$(150\ kPa)(3.2\ m^3) = (2\ kgs) R (303\ K)$$

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

Hydrogen

$P_1 = 100\ kPa$

$t_1 = 20°C$

$m_{added} = 1.5\ kgs$

$t_2 = 30°C$

$P_2 = 250\ kPa$

$R_{H_2} = 4.125\ KJ/kg\text{-}K$

a) Volume of the tank

$$P_1 V_1 = m R T_1$$

$$(100\ kPa) V_1 = m_1 (4.125\ KJ/kg\text{-}K)(20+273)K$$

$$V_1 = 12.0863\ m_1$$

for m_1; $V_1 = V_2$

$$P_2 V_2 = m_2 R T_2$$

$$(250\ kPa)(12.0863\ m_1) = (m_1 + 1.5\ kgs)(4.125\ KJ/kg\text{-}K)(30+273)K$$

$$m_1 = 1.0581\ kg$$

therefore;

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

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

b.) Final mass;

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

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

$P_1 = 275\ kPag$

$t_1 = 28°C$

Bursting pressure

$P_B = 1800\ kPag$

$t_B = ?$

$$\frac{P_1 \cancel{V_1}}{T_1} = \frac{P_2 \cancel{V_2}}{T_2}$$

$$\frac{(275 + 101.325\ kPa)}{(28 + 273)K} = \frac{(1800 + 101.325\ kPa)}{T_B}$$

$T_B = 1520.75\ K$

$$\boxed{t_B = 1247.75°C}$$

14

$V_1 = V_2 = 2 m^3$ Helium

$P_1 = 320 kPag$

$T_1 = 315 K$

$P_2 = 200 kPag$

$T_2 = 300 K$

a) mass of Helium leaked out

$P_1 V_1 = m_1 R T_1$

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

$m_1 = 1.28795\ kg$

$P_2 V_2 = m_2 R T_2$

$(200 + 101.325) kPa (2 m^3) = m_2 (2.077 kJ/kg\text{-}K)(300 K)$

$\boxed{m_2 = 1.22396\ kg}$

(b.) Hence the mass leaked out

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

$V_A = 90L$
$P_A = 3500 kPa$
$t_A = 60°C$

$V_B = ?$
$P_B = 200 kPa$
$t_B = 20°C$

$P_m = 1800 kPa$
$t_m = 32°C$
$V_m = V_a + V_B$
$V_m = 0.09 m^3 + V_B$

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

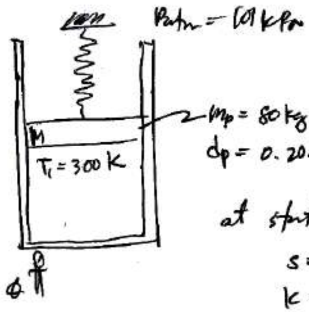
$$\frac{(1800 kPa)(V_m)}{305 K} = \frac{(3500 kPa)(0.09 m^3)}{333 K} + \frac{(200 kPa)(V_B)}{293 K}$$

$$5.9016 V_m = 0.9459 + 0.6826 V_B$$

$$V_B = 0.07947 m^3$$

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

16



$m_p = 80\,kg$

$d_p = 0.20\,m$

at state 2, when heat is added

$s = 0.18\,m$

$k = 30\,kN/m$

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

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

$$\boxed{P_1 = 125.9809\,kPa}$$

(b) Final temperature of air

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

$$P_2 = 297.8682\,kPa$$

$$P_2V_2 = mRT_2$$

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

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

for V_1 is

$$P_1V_1 = mRT_1$$

$$(125.9809\,kPa)V_1 = (0.1\,kg)(0.287\,kJ/kg\text{-}K)(300\,K)$$

$$V_1 = 0.06834\,m^3$$

$$0.0683\,m^3 = \frac{\pi(0.20\,m)^2}{4}H$$

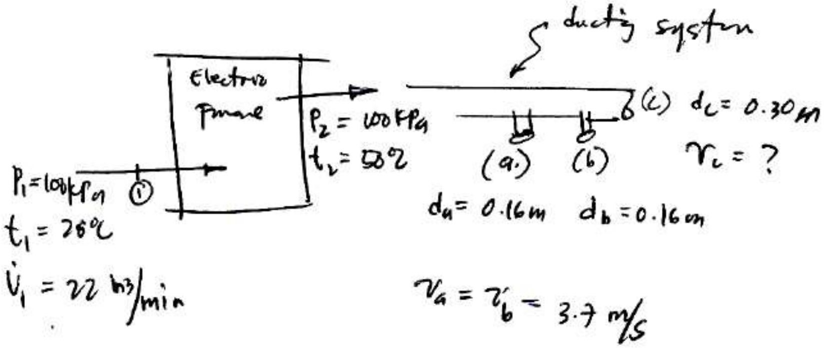
$$H = 2.19545\,m$$

$$V_2 = \frac{\pi(0.20\,m)^2}{4}(2.19545\,m + 0.18\,m) = 0.07399\,m^3$$

$$(297.8682\,kPa)(0.07399\,m^3) = (0.1\,kg)(0.287\,kJ/kg\text{-}K)T_2$$

$$\boxed{T_2 = 768.\,K}$$

17



a) mass flow rate of air exiting the furnace

$$P_1 V_1 = m R T_1$$

$$(100\,kPa)\left(\frac{22}{60}\,\frac{m^3}{s}\right) = \dot{m}\left(0.287\,kJ/kg\text{-}K\right)(20+273)\,K$$

$$\boxed{m_1 = 0.4244\,kg/s}$$

b) velocity of air at duct c

mass balance

$$m_1 = m_a + m_b + m_c$$

$$m_a = m_b$$

$$PV = mRT$$

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

$$m_a = m_b = 0.08025\,kg/s$$

hence;

$$0.4244\,kg/s = 0.08025\,kg/s + 0.08025\,kg/s + m_c$$

$$m_c = 0.263899\,kg/s$$

Solving for Velocity;

$$P_c V_c = m_c R T_c$$

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

$$V_c = 0.24464\,m^3/s$$

$$V_c = A v$$

$$0.24464\,m^3/s = \frac{\pi(0.30\,m)^2}{4}\,v_c$$

$$\boxed{v_c = 3.4609\,m/s}$$