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1. (25 points) A 10-ft$^3$ tank contains oxygen initially at 14.7 psia and 80°F. A paddle wheel within the tank is rotated until the pressure inside rises to 20 psia. During the process 20 Btu of heat is lost to the surroundings. Determine the paddle-wheel work done in Btu. (Neglect the energy stored in the paddle wheel.)

(1.)

$P_1 = 14.7$ psia

$T = 80°F = 539.67$

$v_1 = 12.209$

$R = .3353$

$PV = mRT$

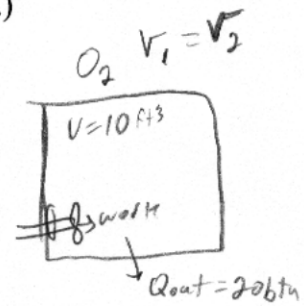
$Pv = RT$

$v = \frac{RT}{P} = \frac{.3353 \cdot 539.67}{14.7}$

$v = 12.309$

$m = \frac{V}{v} = .819$ lbm ✓

$u_1 = 2672.139$




$P_2 = 20$ psia

$T = \frac{Pv}{R} = \frac{20 \cdot 12.309}{.3353}$

$T_2 = 734.208$ ✓

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

$u_2 =$

$u_2 - u_1 = c_v(T_2 - T_1)$ ✓

$c_{v@636} = .17844$ (avg T cap)

$-Q + W = -m\, c_v(T_2 - T_1)$ -2

$+20 + W = .819$ lbm $.17844(734.208 - 539.67)$

$W = .819 \cdot .17844\,(194.538) + 20$

$W = 48.43$ btu

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2. (25 points) Steam at 5 MPa and 400°C enters a nozzle steadily with a velocity of 80 m/s, and it leaves at 2 MPa and 300°C. The inlet area of the nozzle is 50 $cm^2$, and heat is being lost at a rate of 120 kJ/s. Determine the exit velocity of the steam in m/s.

① Steam
$P_1 = 5$ MPa
$T_1 = 400°C$
$V_1 = 80$ m/s
$A_1 = 50\ cm^2$
$h_1 = 3196.7$ ✓
$v_1 = .057184$

$\dot{m}_1 = \dot{m}_2 = \dot{m}$


② $P_2 = 2$ MPa
$T_2 = 300°C$
$h_2 = 3024.2$ ✓

$\dot{m} = \frac{1}{v} VA$

$\dot{m} = \frac{\rho}{} VA$

$\dot{m} = \frac{1}{.057184} \cdot 80 \cdot .005\ m^2$

$\dot{m} = 6.9204$ ✓

$\dot{Q} = \dot{m}_2\left(h_2 + \frac{V_2^2}{2}\right) - \dot{m}_1\left(h_1 + \frac{V_1^2}{2}\right)$

$\dot{Q} = \dot{m}\left(h_2 - h_1 + \frac{V_2^2 - V_1^2}{2}\right)$

$-120 = \dot{m}\left(3024.2 - 3196.7 + \frac{V_2^2 - 80^2}{2}\right)$

$-120 = 6.9204\left(-172.5 + \frac{V_2^2 - 80^2}{2}\right)$

$V_2 = 81.91$ m/s ✗

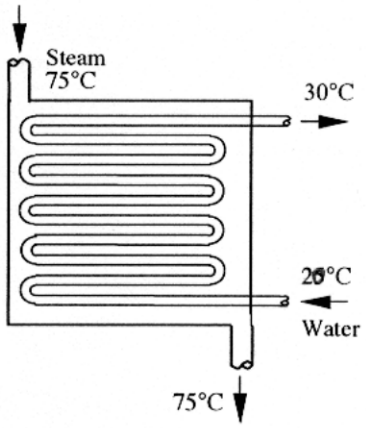
$1\ kJ / 1000\ m^2/s^2$

−1

−1

10/2

3. (25 points) Saturated steam is to be condensed in the condenser of a steam power plant at a temperature of 75 °C with cooling water from a nearby lake, which enters the tubes of the condenser at 20 °C at a rate of 135 kg/s and leaves at 30 °C. Determine the rate of condensation of the steam in the condenser in kg/s.




① satsteam $\dot{m}_1 = \dot{m}_2 = \dot{m}_s$ ② Sat mix

$T = 75°C$

$h_1 = 2634.6$

3. $T_3 = 20°C$

$\dot{m}_3 = 135$ kg/s

④ $T_4 = 30°C$

$\dot{m}_3 = \dot{m}_4 = \dot{m}_w$

$C_{pv} = 4.18$

$\dot{m}_1 (h_1) \; \dot{m}_3 h_3 = \dot{m}_2 h_2 \; \dot{m}_4 h_4$

$\dot{m}_s (h_1 - h_2) = \dot{m}_w (h_4 - h_3)$ ✓

$\dot{m}_s = \dfrac{\dot{m}_w (h_4 - h_3)}{(h_1 - h_2)} = \dfrac{\dot{m}_w C_{pv} (T_4 - T_3)}{C_{pv} (T_1 - T_2)} =$

$Q + \dot{m}_w (h_3) = \dot{m}_w (h_4)$

$Q = \dot{m}_w (h_4 - h_3)$

$Q = 135 (4.18 (T_4 - T_3) = 135 (4.18 (30 - 20))$

$Q = 5643$ kW

$-5643 + \dot{m}_s (h_1) = \dot{m}_s (h_2)$

$\dot{m}_s (h_2 - h_1) = 5643$

$\dot{m}_s = \dfrac{5643}{h_2 - h_1}$

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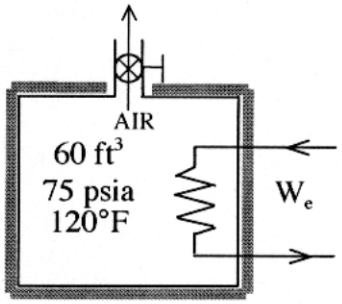
4. (25 points) An insulated 60-ft$^3$ rigid tank contains air at 75 psia and 120°F. A valve connected to the tank is now opened, and air is allowed to escape until the pressure inside drops to 30 psia. The air temperature during this process is maintained constant by an electric resistance heater placed in the tank. Determine the electrical work done during this process.




① $P = 75$ psia

$T = 120°F = 580R$

$V = 60 ft^3$

$v_1 = \frac{RT}{P} = \frac{580 \cdot .3704}{75} = 2.864$

$m_1 = \frac{60}{2.864} = 20.9466$ ✓

$u_1 = 94.90$

② $P = 30$ psia

$T = 120 = 580$

$V = 60$

$v_2 = 7.161$

$m_2 = 8.378$ ✓

$u_2 = 94.90$

ext

$T = 130 = 580$

$m_e = 12.567$ $\quad m_1 - m_2 = m_e$

$h = 138.66$ $\quad 20.94 - 8.37 = 12.567$

$-W = m_{in}(h) + (m_2 u_2 - m_1 u_1)$

$-W = +12.567(138.66) + (8.378(94.90) - 20.9466(94.90))$

$-W = -2986.36$

$W_{in} = 2986.36$ X