

{Question #1}

$$g=9.81[\text{m/s}^2]$$

$$A=0.01[\text{m}^2]$$

$$m=50[\text{kg}]$$

$$P_{\text{atm}}=1[\text{bar}]$$

$$P=P_{\text{atm}}+((m \cdot g)/A) \cdot \text{convert}(\text{Pa}, \text{bar}) \quad \{\text{Pressure: } P = 1.491 \text{ bar}\}$$

SOLUTION

Unit Settings: SI C kPa kJ mass deg

$$A = 0.01 \quad [\text{m}^2]$$

$$P = 1.491 \quad [\text{bar}]$$

$$g = 9.81 \quad [\text{m/s}^2]$$

$$P_{\text{atm}} = 1 \quad [\text{bar}]$$

$$m = 50 \quad [\text{kg}]$$

No unit problems were detected.

{Question #2}

{Part A}

 $P_1 = 14.7 \cdot \text{convert}(\text{psi}, \text{kPa})$ $\text{TSat}_1 = \text{converttemp}(\text{C}, \text{F}, \text{t_sat}(\text{Water}, P=P_1))$ {Saturation Temperature: $\text{TSat}_1 = 212 \text{ F}$ }

{Part B}

 $P_2 = 24.58 \cdot \text{convert}(\text{inHG}, \text{kPa})$ $\text{TSat}_2 = \text{converttemp}(\text{C}, \text{F}, \text{t_sat}(\text{Water}, P=P_2))$ {Saturation Temperature: $\text{TSat}_2 = 202.2 \text{ F}$ }

{Part C}

 $P_3 = 30 [\text{kPa}]$ $\text{TSat}_3 = \text{converttemp}(\text{C}, \text{F}, \text{t_sat}(\text{Water}, P=P_3))$ {Saturation Temperature: $\text{TSat}_3 = 156.4 \text{ F}$ }

SOLUTION

Unit Settings: SI C kPa kJ mass deg

 $P_1 = 101.4 [\text{kPa}]$ $\text{TSat}_1 = 212 [\text{F}]$ $P_2 = 83.24 [\text{kPa}]$ $\text{TSat}_2 = 202.2 [\text{F}]$ $P_3 = 30 [\text{kPa}]$ $\text{TSat}_3 = 156.4 [\text{F}]$

No unit problems were detected.

{Question 3.21}

$g=9.81[\text{m/s}^2]$
 $P_{\text{atm}}=100[\text{kPa}]$
 $A=0.01[\text{m}^2]$
 $m_{\text{piston}}=50[\text{kg}]$
 $m_{\text{water}}=0.1[\text{kg}]$
 $T_{\text{water}}=100[\text{C}]$

$P_{\text{water}}=P_{\text{atm}}+((m_{\text{piston}}*g)/A)*\text{convert}(\text{Pa}, \text{kPa})$ {Pressure Water: $P_{\text{water}} = 149.1 \text{ kPa}$ }
 $V_{\text{water}}=m_{\text{water}}*\text{volume}(\text{Water}, T=T_{\text{water}}, P=P_{\text{water}})*\text{convert}(\text{m}^3, \text{cm}^3)$ {Volume Water: $V_{\text{water}} = 104.3 \text{ cm}^3$ }

SOLUTION

Unit Settings: SI C kPa kJ mass deg

 $A = 0.01 \text{ [m}^2\text{]}$ $m_{\text{water}} = 0.1 \text{ [kg]}$ $T_{\text{water}} = 100 \text{ [C]}$ $g = 9.81 \text{ [m/s}^2\text{]}$ $P_{\text{atm}} = 100 \text{ [kPa]}$ $V_{\text{water}} = 104.3 \text{ [cm}^3\text{]}$ $m_{\text{piston}} = 50 \text{ [kg]}$ $P_{\text{water}} = 149.1 \text{ [kPa]}$

No unit problems were detected.

{Question 2.A-3}

 $V = 8000 \cdot \text{convert}(\text{cm}^3, \text{m}^3)$
 $x_1 = 0.05$
 $T_1 = 140[\text{C}]$

{Part A}

 $SV = \text{volume}(\text{Steam}, T=T_1, x=x_1)$ {Specific Volume: $SV = 0.02645 \text{ m}^3/\text{kg}$ }

 $P_1 = \text{pressure}(\text{Steam}, T=T_1, v=SV)$ {Pressure: $P_1 = 361.5 \text{ kPa}$ }

 $\text{TEST} = \text{quality}(\text{Steam}, T=T_1, v=SV)$

{Part B}

 $m_{\text{total}} = V/SV$ {Total Mass: $m_{\text{total}} = 0.3024 \text{ kg}$ }

 $m_{\text{water}} = m_{\text{total}} \cdot (1 - x_1)$ {Water Mass: $m_{\text{water}} = 0.2873 \text{ kg}$ }

 $m_{\text{vapor}} = m_{\text{total}} \cdot x_1$ {Vapor Mass: $m_{\text{vapor}} = 0.01512 \text{ kg}$ }

{Part C}

 $V_{\text{water}} = SV \cdot m_{\text{water}}$ {Water Volume: $V_{\text{water}} = 0.0076 \text{ m}^3$ }

 $V_{\text{vapor}} = SV \cdot m_{\text{vapor}}$ {Vapor Volume: $V_{\text{vapor}} = 0.0004 \text{ m}^3$ }

 $T_2 = 200[\text{C}]$

{Part D}

 $P_2 = \text{pressure}(\text{Steam}, T=T_2, v=SV)$ {Pressure: $P_2 = 1,555 \text{ kPa}$ }

 $x_2 = \text{quality}(\text{Steam}, T=T_2, v=SV)$ {Quality: $x_2 = 20.07 \%$ }

{Part E}

 $m_{\text{water}_2} = V/SV \cdot (1 - x_2)$ {Water Mass: $m_{\text{water}_2} = 0.2418 \text{ kg}$ }

SOLUTION

Unit Settings: SI C kPa kJ mass deg

 $m_{\text{total}} = 0.3024$ [kg]

 $m_{\text{water}_2} = 0.2418$ [kg]

 $SV = 0.02645$ [m³/kg]

 $T_2 = 200$ [C]

 $V_{\text{water}} = 0.0076$ [m³]

 $m_{\text{vapor}} = 0.01512$ [kg]

 $P_1 = 361.5$ [kPa]

 $\text{TEST} = 0.05$
 $V = 0.008$ [m³]

 $x_1 = 0.05$
 $m_{\text{water}} = 0.2873$ [kg]

 $P_2 = 1555$ [kPa]

 $T_1 = 140$ [C]

 $V_{\text{vapor}} = 0.0004$ [m³]

 $x_2 = 0.2007$

No unit problems were detected.

{Question 4.007}

 $P_1 = 10 [\text{bar}]$ $T_1 = 20 [\text{C}]$ $P_2 = 3.0 [\text{bar}]$ $h_1 = \text{enthalpy}(\text{Ammonia}, P=P_1 * \text{convert}(\text{bar}, \text{kPa}), T=T_1)$ $h_2 = h_1$ $T_2 = \text{temperature}(\text{Ammonia}, P=P_2 * \text{convert}(\text{bar}, \text{kPa}), h=h_2) \{\text{Temperature: } T_2 = -9.231 \text{C}\}$ $x_2 = \text{quality}(\text{Ammonia}, P=P_2 * \text{convert}(\text{bar}, \text{kPa}), h=h_2) \{\text{Quality: } x_2 = 10.54 \%\}$

SOLUTION

Unit Settings: SI C kPa kJ mass deg

 $h_1 = 293.9 [\text{kJ/kg}]$ $h_2 = 293.9 [\text{kJ/kg}]$ $P_1 = 10 [\text{bar}]$ $P_2 = 3 [\text{bar}]$ $T_1 = 20 [\text{C}]$ $T_2 = -9.231 [\text{C}]$ $x_2 = 0.1054$

No unit problems were detected.

EES suggested units (shown in purple) for h_2 .

{Question 4.75}

P_3=5[bar]
 x_3=0.20
 P_4=5[bar]
 T_4=20[C]

P_1=1[bar]
 T_1=305[K]
 AV_air=50[m^3/min]
 P_2=0.95[bar]
 T_2=295[K]

{Part A}

{Use first law equation to find mass flow rate of the refrigerant. We can neglect heat loss, work, kinetic energy, and potential energy}

0=mdot_air*(h_1-h_2)+mdot_ref*(h_3-h_4)
 mdot_air=AV_air*P_1*convert(bar,kPa)/(R#/molarmass(Air))/T_1
 h_1=enthalpy(Air, T=converttemp(K,C,T_1))
 h_2=enthalpy(Air, T=converttemp(K,C,T_2))
 h_3=enthalpy(R134a, P=P_3*convert(bar,kPa), x=x_3)
 h_4=enthalpy(R134a, T=T_4, P=P_4*convert(bar,kPa))

{Solving the The first law equation we find mdot_ref}

{Mass Flow Rate of Refrigerant: mdot_ref = 3.752 kg/min}

{Part B}

{Find heat transfer using first law of only the refrigerant. We can neglect work, kinetic energy, and potential energy}

0=Qdot+mdot_ref*(h_3-h_4)

{Solving the The first law equation we find Qdot}

{Heat Transfer: Qdot = 573.8 kJ/min}

kJ=0
 min=1

SOLUTION

Unit Settings: SI C kPa kJ mass deg

AV _{air} = 50 [m ³ /min]	h ₁ = 305.5 [kJ/kg]	h ₂ = 295.4 [kJ/kg]
h ₃ = 110.5 [kJ/kg]	h ₄ = 263.5 [kJ/kg]	kJ = 0
mdot _{air} = 57.11 [kg/min]	mdot _{ref} = 3.752 [kg/min]	min = 1
P ₁ = 1 [bar]	P ₂ = 0.95 [bar]	P ₃ = 5 [bar]
P ₄ = 5 [bar]	Qdot = 573.8 [kJ/min]	T ₁ = 305 [K]
T ₂ = 295 [K]	T ₄ = 20 [C]	x ₃ = 0.2

No unit problems were detected.

EES suggested units (shown in purple) for h_1 h_2 h_3 h_4 .

{Question 4.009}

\$UnitSystem ENG

T_1=40[F]

P_1=80[psi]

T_2=160[F]

P_2=200[psi]

T_3=90[F]

P_3=200[psi]

T_air_1=1[F]

P_air_1=14.7[psi]

Vdot_air=1[ft^3/min] {Vdot[ft^3/min] = VA[ft^3/min]}

T_air_2=110[F]

{Part A}

{Use first law equation to solve for Vdot_ref. We are observing the condensor so we can neglect heat transfer, work, kinetic energy and potential energy}

0=mdot_air*(h_air_1-h_air_2)+mdot_ref*(h_2-h_3)

{Alternate Method => mdot_air*cp(Air,T=T_air_1)*(converttemp(F,R,T_air_2)-converttemp(F,R,T_air_1))=mdot_ref*(h_2-h_3)}

{We need mdot_air in order to find mdot_ref, mdot_air = VA*rho, so we need to find density}

mdot_air=Vdot_air*density(Air, T=T_air_1, P=P_air_1)

h_air_1=enthalpy(Air, T=T_air_1)

h_air_2=enthalpy(Air, T=T_air_2)

h_2=enthalpy(R22, T=T_2, P=P_2)

h_3=enthalpy(R22, T=T_3, P=P_3)

{Solving the first law equation with the values we gathered we can calculate mdot_ref}

{Mass Flow Rate of Refrigerant: mdot_ref = 0.02531 lb/min}

{Part B}

{To find the work of the compressor we need to use the first law equation for only the refrigerant between states 1 and 2. We neglect heat loss, kinetic energy, and potential energy. WE DO NOT NEGLECT WORK}

0=Wdot+(mdot_ref*(h_1-h_2)*convert(Btu/min, hp))

h_1=enthalpy(R22, T=T_1, P=P_1)

{Solve the first law equation to find work}

{Compressor Power: Wdot = 0.01012 hp}

SOLUTION

Unit Settings: Eng F psia mass deg

h1 = 175 [Btu/lb_m]

h3 = 103 [Btu/lb_m]

hair,2 = 136.3 [Btu/lb_m]

mdotref = 0.02531 [lb_m/min]

P2 = 200 [psi]

Pair,1 = 14.7 [psi]

T2 = 160 [F]

Tair,1 = 1 [F]

Vdotair = 1 [ft^3/min]

h2 = 192 [Btu/lb_m]

hair,1 = 110.1 [Btu/lb_m]

mdotair = 0.08613 [lb_m/min]

P1 = 80 [psi]

P3 = 200 [psi]

T1 = 40 [F]

T3 = 90 [F]

Tair,2 = 110 [F]

Wdot = 0.01012 [hp]

No unit problems were detected.

{Problem 6.77}

Qdot_hot=15[kW]
Wdot_cycle=3.2[kW]
T_inside=22[C]
T_outside=-22[C]

{Energy Rate Balance Equation}

$$0 = \dot{Q}_{\text{hot}} + \dot{Q}_{\text{cold}} - \dot{W}_{\text{cycle}}$$

{Entropy Rate Balance Equation}

$$0 = \dot{Q}_{\text{hot}}/T_{\text{inside}} + \dot{Q}_{\text{cold}}/T_{\text{outside}} + \dot{\sigma}$$

{Sigma-dot: $\dot{\sigma} = -1.218 \text{ kW/C}$ }

{Because Sigma-dot is negative the manufactures claims are false}

SOLUTION

Unit Settings: Eng F psia mass deg

Qdotcold = -11.8 [kW]

Tinside = 22 [C]

Qdohot = 15 [kW]

Toutside = -22 [C]

$\dot{\sigma} = -1.218 \text{ [kW/C]}$

Wdotcycle = 3.2 [kW]

No unit problems were detected.

{Question 6.145}

$T_1 = 190 [\text{K}]$
 $P_1 = 100 [\text{kPa}]$
 $P_2 = 330 [\text{kPa}]$
 $\text{efficiency} = 90.3$

$\text{efficiency} = W_s / W$
 $W_s = h_{2s} - h_1$
 $W = h_2 - h_1$

$h_1 = \text{enthalpy}(\text{Air}, T = \text{converttemp}(\text{K}, \text{C}, T_1))$
 $s_1 = \text{entropy}(\text{Air}, T = \text{converttemp}(\text{K}, \text{C}, T_1), P = P_1)$
 $s_1 = s_{2s}$
 $h_{2s} = \text{enthalpy}(\text{Air}, P = P_2, s = s_{2s})$

{Using the isentropic efficiency equation it is possible to find h_2 and then W }
 {Work Input: $W = 0.8597 \text{ kJ/kg}$ }

SOLUTION

Unit Settings: SI C kPa kJ mass deg

$\text{efficiency} = 90.3$

$h_{2s} = 267.7 [\text{kJ/kg}]$

$s_1 = 5.248 [\text{kJ/kg-K}]$

$W = 0.8597 [\text{kJ/kg}]$

$h_1 = 190.1 [\text{kJ/kg}]$

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

$s_{2s} = 5.248 [\text{kJ/kg-K}]$

$W_s = 77.63 [\text{kJ/kg}]$

$h_2 = 191 [\text{kJ/kg}]$

$P_2 = 330 [\text{kPa}]$

$T_1 = 190 [\text{K}]$

No unit problems were detected.

{Problem 6.007}

 $\dot{m} = 1.2 \text{ [kg/s]}$ $T_1 = 50 \text{ [C]}$ $P_1 = 1.5 * \text{convert}(\text{MPa}, \text{kPa})$ $P_2 = 15 * \text{convert}(\text{MPa}, \text{kPa})$ $W_{\text{actual}} = 21 \text{ [kW]}$ $W_{\text{reversible}} = \dot{m} * v * (P_2 - P_1)$ {Work Required by a Reversible Pump: $W_{\text{reversible}} = 16.39 \text{ kW}$ } $v = \text{volume}(\text{Water}, T = T_1, P = P_1)$ $n = W_{\text{reversible}} / W_{\text{actual}}$ {Isentropic Efficiency: $n = 78.03\%$ }

SOLUTION

Unit Settings: SI C kPa kJ mass deg

 $\dot{m} = 1.2 \text{ [kg/s]}$ $P_2 = 15000 \text{ [kPa]}$ $W_{\text{actual}} = 21 \text{ [kW]}$ $n = 0.7803$ $T_1 = 50 \text{ [C]}$ $W_{\text{reversible}} = 16.39 \text{ [kW]}$ $P_1 = 1500 \text{ [kPa]}$ $v = 0.001011 \text{ [m}^3\text{/kg]}$

No unit problems were detected.

EES suggested units (shown in purple) for v .