TD 3(Solutionnaire)

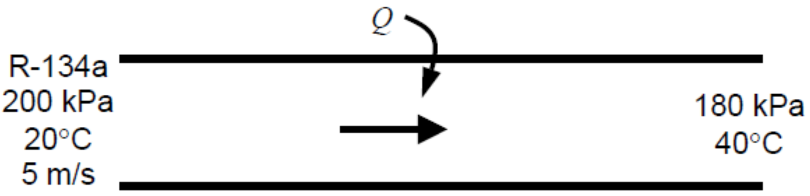
5.5

The amount of mass or energy entering a control volume does not have to be equal to the amount of mass or energy leaving during an unsteady-flow process

5.5

Non, sauf si la densité est constante

5.16



Properties The specific volumes of R-134a at the inlet and exit are (Table A-13)

$$\left.\begin{array}{l} P_1 = 200\text{ kPa} \\ T_1 = 20°\text{C} \end{array}\right\} \upsilon_1 = 0.1142\text{ m}^3/\text{kg} \qquad \left.\begin{array}{l} P_1 = 180\text{ kPa} \\ T_1 = 40°\text{C} \end{array}\right\} \upsilon_2 = 0.1374\text{ m}^3/\text{kg}$$

Analysis (*a*) (*b*) The volume flow rate at the inlet and the mass flow rate are

$$\dot{V}_1 = A_c V_1 = \frac{\pi D^2}{4} V_1 = \frac{\pi (0.28\text{ m})^2}{4}(5\text{ m/s}) = \mathbf{0.3079\ m^3/s}$$

$$\dot{m} = \frac{1}{\upsilon_1} A_c V_1 = \frac{1}{\upsilon_1}\frac{\pi D^2}{4} V_1 = \frac{1}{0.1142\text{ m}^3/\text{kg}}\frac{\pi (0.28\text{ m})^2}{4}(5\text{ m/s}) = \mathbf{2.696\ kg/s}$$

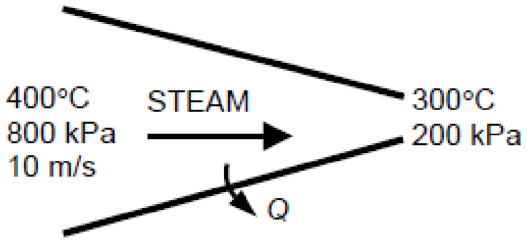
(c) Noting that mass flow rate is constant, the volume flow rate and the velocity at the exit of the pipe are determined from

$$\dot{V}_2 = \dot{m}\upsilon_2 = (2.696\text{ kg/s})(0.1374\text{ m}^3/\text{kg}) = \mathbf{0.3705\ m^3/s}$$

$$V_2 = \frac{\dot{V}_2}{A_c} = \frac{0.3705\text{ m}^3/\text{s}}{\dfrac{\pi (0.28\text{ m})^2}{4}} = \mathbf{6.02\ m/s}$$

5.38

Assumptions **1** This is a steady-flow process since there is no change with time. **2** Potential energy change is negligible. **3** There are no work interactions.



Analysis We take the steam as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as

Energy balance:

$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\text{Rate of net energy transfer by heat, work, and mass}} = \underbrace{\Delta \dot{E}_{system}}_{\text{Rate of change in internal, kinetic, potential, etc. energies}}^{\nearrow 0 \text{ (steady)}} = 0$$

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

$$\dot{m}\left(h_1 + \frac{V_1^2}{2}\right) = \dot{m}\left(h_2 + \frac{V_2^2}{2}\right) + \dot{Q}_{out} \quad \text{since } \dot{W} \cong \Delta\text{pe} \cong 0)$$

or

$$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2} + \frac{\dot{Q}_{out}}{\dot{m}}$$

The properties of steam at the inlet and exit are (Table A-6)

$$\left.\begin{array}{l} P_1 = 800 \text{ kPa} \\ T_1 = 400°\text{C} \end{array}\right\} \begin{array}{l} v_1 = 0.38429 \text{ m}^3/\text{kg} \\ h_1 = 3267.7 \text{ kJ/kg} \end{array}$$

$$\left.\begin{array}{l} P_2 = 200 \text{ kPa} \\ T_1 = 300°\text{C} \end{array}\right\} \begin{array}{l} v_2 = 1.31623 \text{ m}^3/\text{kg} \\ h_2 = 3072.1 \text{ kJ/kg} \end{array}$$

The mass flow rate of the steam is

$$\dot{m} = \frac{1}{v_1} A_1 V_1 = \frac{1}{0.38429 \text{ m}^3/\text{s}} (0.08 \text{ m}^2)(10 \text{ m/s}) = 2.082 \text{ kg/s}$$

Substituting,

$$3267.7 \text{ kJ/kg} + \frac{(10 \text{ m/s})^2}{2}\left(\frac{1 \text{ kJ/kg}}{1000 \text{ m}^2/\text{s}^2}\right) = 3072.1 \text{ kJ/kg} + \frac{V_2^2}{2}\left(\frac{1 \text{ kJ/kg}}{1000 \text{ m}^2/\text{s}^2}\right) + \frac{25 \text{ kJ/s}}{2.082 \text{ kg/s}}$$

$$\longrightarrow V_2 = \mathbf{606 \text{ m/s}}$$

The volume flow rate at the exit of the nozzle is

$$\dot{V}_2 = \dot{m} v_2 = (2.082 \text{ kg/s})(1.31623 \text{ m}^3/\text{kg}) = \mathbf{2.74 \text{ m}^3/\text{s}}$$

5.44

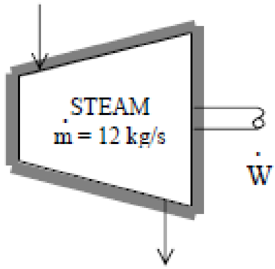
Assumptions **1** This is a steady-flow process since there is no change with time. **2** Potential energy changes are negligible. **3** The device is adiabatic and thus heat transfer is negligible.

Properties From the steam tables (Tables A-4 through 6)

$$\left.\begin{aligned} P_1 &= 10 \text{ MPa} \\ T_1 &= 450°\text{C} \end{aligned}\right\} \begin{aligned} v_1 &= 0.029782 \text{ m}^3/\text{kg} \\ h_1 &= 3242.4 \text{ kJ/kg} \end{aligned}$$

and

$$\left.\begin{aligned} P_2 &= 10 \text{ kPa} \\ x_2 &= 0.92 \end{aligned}\right\} h_2 = h_f + x_2 h_{fg} = 191.81 + 0.92 \times 2392.1 = 2392.5 \text{ kJ/kg}$$



Analysis (a) The change in kinetic energy is determined from

$$\Delta ke = \frac{V_2^2 - V_1^2}{2} = \frac{(50 \text{ m/s})^2 - (80 \text{ m/s})^2}{2}\left(\frac{1 \text{ kJ/kg}}{1000 \text{ m}^2/\text{s}^2}\right) = -1.95 \text{ kJ/kg}$$

(*b*) There is only one inlet and one exit, and thus $\dot{m}_1 = \dot{m}_2 = \dot{m}$. We take the turbine as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as

$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\substack{\text{Rate of net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta \dot{E}_{system}^{\nearrow 0 \text{ (steady)}}}_{\substack{\text{Rate of change in internal, kinetic,} \\ \text{potential, etc. energies}}} = 0$$

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

$$\dot{m}(h_1 + V_1^2/2) = \dot{W}_{out} + \dot{m}(h_2 + V_2^2/2) \quad (\text{since } \dot{Q} \cong \Delta pe \cong 0)$$

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

Then the power output of the turbine is determined by substitution to be

$$\dot{W}_{out} = -(12 \text{ kg/s})(2392.5 - 3242.4 - 1.95)\text{kJ/kg} = \mathbf{10.2 \ MW}$$

(*c*) The inlet area of the turbine is determined from the mass flow rate relation,

$$\dot{m} = \frac{1}{v_1} A_1 V_1 \longrightarrow A_1 = \frac{\dot{m} v_1}{V_1} = \frac{(12 \text{ kg/s})(0.029782 \text{ m}^3/\text{kg})}{80 \text{ m/s}} = \mathbf{0.00447 \ m^2}$$

5.79

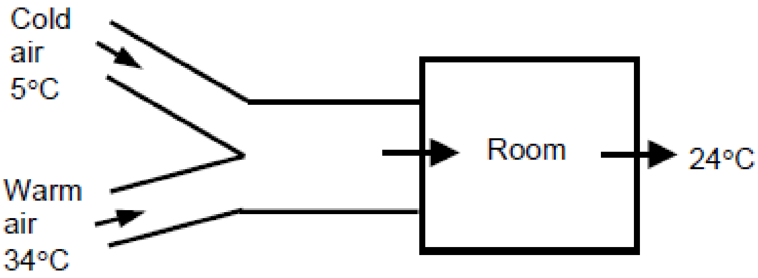
Assumptions **1** This is a steady-flow process since there is no change with time. **2** Kinetic and potential energy changes are negligible. **3** There are no work interactions. **4** The device is adiabatic and thus heat transfer is negligible.

Properties The gas constant of air is R = 0.287 kPa.m^3/kg.K. The enthalpies of air are obtained from air table (Table A-17) as

$$h_1 = h_{@278\text{ K}} = 278.13\text{ kJ/kg}$$

$$h_2 = h_{@307\text{ K}} = 307.23\text{ kJ/kg}$$

$$h_{\text{room}} = h_{@297\text{ K}} = 297.18\text{ kJ/kg}$$



Analysis (*a*) We take the mixing chamber as the system, which is a control volume since mass crosses the boundary. The mass and energy balances for this steady-flow system can be expressed in the rate form as

Mass balance:

$$\dot m_{\text{in}} - \dot m_{\text{out}} = \Delta \dot m_{\text{system}}^{\nearrow 0 \text{ (steady)}} = 0 \rightarrow \dot m_{\text{in}} = \dot m_{\text{out}} \rightarrow \dot m_1 + 1.6\dot m_1 = \dot m_3 = 2.6\dot m_1 \;\; \text{since} \;\; \dot m_2 = 1.6\dot m_1$$

Energy balance:

$$\underbrace{\dot E_{\text{in}} - \dot E_{\text{out}}}_{\text{Rate of net energy transfer by heat, work, and mass}} = \underbrace{\Delta \dot E_{\text{system}}^{\nearrow 0 \text{ (steady)}}}_{\text{Rate of change in internal, kinetic, potential, etc. energies}} = 0$$

$$\dot E_{\text{in}} = \dot E_{\text{out}}$$

$$\dot m_1 h_1 + \dot m_2 h_2 = \dot m_3 h_3 \quad (\text{since } \dot Q \cong \dot W \cong \Delta\text{ke} \cong \Delta\text{pe} \cong 0)$$

Combining the two gives $\dot m_1 h_1 + 1.6\dot m_1 h_2 = 2.6\dot m_1 h_3 \;\; or \;\; h_3 = (h_1 + 1.6 h_2)/2.6$

Substituting,

$$h_3 = (278.13 + 1.6 \times 307.23)/2.6 = 296.04\text{ kJ/kg}$$

From air table at this enthalpy, the mixture temperature is

$$T_3 = T_{@h=296.04\text{ kJ/kg}} = 295.9\text{ K} = \mathbf{22.9°C}$$

(*b*) The mass flow rates are determined as follows

$$v_1 = \frac{RT_1}{P} = \frac{(0.287\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(5+273\text{ K})}{105\text{ kPa}} = 0.7599\text{ m}^3/\text{kg}$$

$$\dot m_1 = \frac{\dot V_1}{v_1} = \frac{1.25\text{ m}^3/\text{s}}{0.7599\text{ m}^3/\text{kg}} = 1.645\text{ kg/s}$$

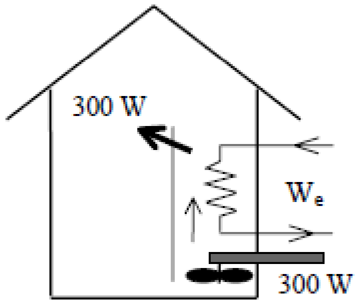
$$\dot m_3 = 2.6\dot m_1 = 2.6(1.645\text{ kg/s}) = 4.277\text{ kg/s}$$

The rate of heat gain of the room is determined from

$$\dot Q_{\text{cool}} = \dot m_3(h_{\text{room}} - h_3) = (4.277\text{ kg/s})(297.18 - 296.04)\text{ kJ/kg} = \mathbf{4.88\text{ kW}}$$

5.94

Assumptions **1** This is a steady-flow process since there is no change with time. **2** Air is an ideal gas with constant specific heats at room temperature. **3** Kinetic and potential energy changes are negligible.
Properties The constant pressure specific heat of air at room temperature is c_p = 1.005 kJ/kg·K (Table A-2)
Analysis We take the *heating duct* as the system, which is a control volume since mass crosses the boundary. There is only one inlet and one exit, and thus $\dot{m}_1 = \dot{m}_2 = \dot{m}$. The energy balance for this steady-flow system can be expressed in the rate form as



$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\substack{\text{Rate of net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta \dot{E}_{system}^{\nearrow 0\ (steady)}}_{\substack{\text{Rate of change in internal, kinetic,} \\ \text{potential, etc. energies}}} = 0$$

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

$$\dot{W}_{e,in} + \dot{W}_{fan,in} + \dot{m}h_1 = \dot{Q}_{out} + \dot{m}h_2 \quad (\text{since } \Delta ke \cong \Delta pe \cong 0)$$

$$\dot{W}_{e,in} + \dot{W}_{fan,in} = \dot{Q}_{out} + \dot{m}(h_2 - h_1) = \dot{Q}_{out} + \dot{m}c_p(T_2 - T_1)$$

Substituting, the power rating of the heating element is determined to be

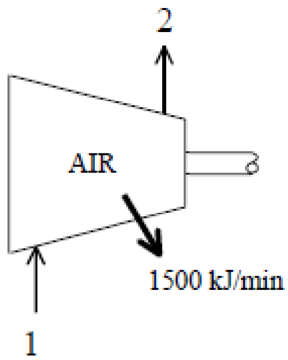
$$\dot{W}_{e,in} = \dot{Q}_{out} + \dot{m}c_p\Delta T - \dot{W}_{fan,in} = (0.3 \text{ kJ/s}) + (0.6 \text{ kg/s})(1.005 \text{ kJ/kg}\cdot{}^\circ\text{C})(7^\circ\text{C}) - 0.3 \text{ kW} = \mathbf{4.22\ kW}$$

5.57 (version anglaise)

Assumptions **1** This is a steady-flow process since there is no change with time. **2** Potential energy changes are negligible. **3** Air is an ideal gas with variable specific heats.
Properties The inlet and exit enthalpies of air are (Table A-17)

$$T_1 = 25^\circ\text{C} = 298 \text{ K} \quad \rightarrow \quad h_1 = h_{@\,298\text{ K}} = 298.2 \text{ kJ/kg}$$
$$T_2 = 347^\circ\text{C} = 620 \text{ K} \quad \rightarrow \quad h_2 = h_{@\,620\text{ K}} = 628.07 \text{ kJ/kg}$$

Analysis We take the compressor as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as



$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\substack{\text{Rate of net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta \dot{E}_{system}^{\nearrow 0\ (steady)}}_{\substack{\text{Rate of change in internal, kinetic,} \\ \text{potential, etc. energies}}} = 0$$

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

$$\dot{W}_{in} + \dot{m}(h_1 + V_1^2/2) = \dot{Q}_{out} + \dot{m}(h_2 + V_2^2/2) \quad (\text{since } \Delta pe \cong 0)$$

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

Substituting, the mass flow rate is determined to be

$$250 \text{ kJ/s} - (1500/60 \text{ kJ/s}) = \dot{m}\left[628.07 - 298.2 + \frac{(90 \text{ m/s})^2 - 0}{2}\left(\frac{1 \text{ kJ/kg}}{1000 \text{ m}^2/\text{s}^2}\right)\right] \rightarrow \dot{m} = \mathbf{0.674\ kg/s}$$

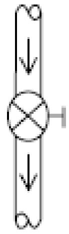
5.66 (version anglaise)

Assumptions **1** This is a steady-flow process since there is no change with time. **2** Kinetic and potential energy changes are negligible. **3** Heat transfer to or from the fluid is negligible. **4** There are no work interactions involved.

Properties The inlet enthalpy of R-134a is, from the refrigerant tables (Tables A-11 through 13),

$$\left.\begin{array}{l} P_1 = 0.7 \text{ MPa} \\ \text{sat. liquid} \end{array}\right\} \begin{array}{l} T_1 = T_{sat} = 26.69^\circ\text{C} \\ h_1 = h_f = 88.82 \text{ kJ/kg} \end{array}$$

P$_1$ = 700 kPa
Sat. liquid



P$_2$ = 160 kPa

Analysis There is only one inlet and one exit, and thus $\dot{m}_1 = \dot{m}_2 = \dot{m}$. We take the throttling valve as the system, which is a control volume since mass crosses the boundary. The energy balance for this steady-flow system can be expressed in the rate form as

$$\dot{E}_{in} - \dot{E}_{out} = \Delta\dot{E}_{system}^{\nearrow 0 \text{ (steady)}} = 0 \rightarrow \dot{E}_{in} = \dot{E}_{out} \rightarrow \dot{m}h_1 = \dot{m}h_2 \rightarrow h_1 = h_2$$

since $\dot{Q} \cong \dot{W} = \Delta ke \cong \Delta pe \cong 0$. Then,

$$\left.\begin{array}{l} P_2 = 160 \text{ kPa} \\ (h_2 = h_1) \end{array}\right\} \begin{array}{l} h_f = 31.21 \text{ kJ/kg}, \quad T_{sat} = -15.60^\circ\text{C} \\ h_g = 241.11 \text{ kJ/kg} \end{array}$$

Obviously $h_f < h_2 < h_g$, thus the refrigerant exists as a saturated mixture at the exit state and thus $T_2 = T_{sat} = -15.60^\circ$C. Then the temperature drop becomes

$$\Delta T = T_2 - T_1 = -15.60 - 26.69 = \mathbf{-42.3^\circ C}$$

The quality at this state is determined from

$$x_2 = \frac{h_2 - h_f}{h_{fg}} = \frac{88.82 - 31.21}{209.90} = 0.2745$$

Thus,

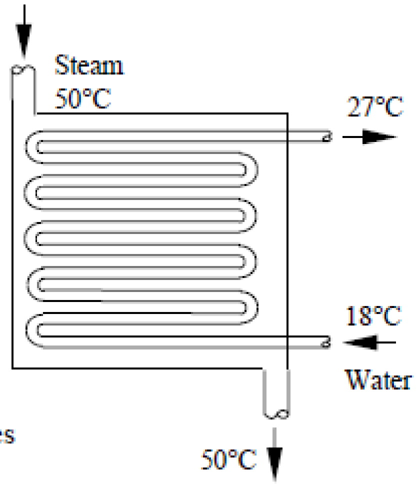
$$v_2 = v_f + x_2 v_{fg} = 0.0007437 + 0.2745 \times (0.12348 - 0.0007437) = \mathbf{0.0344 \ m^3/kg}$$

5.66 (version anglaise)

Assumptions **1** Steady operating conditions exist. **2** The heat exchanger is well-insulated so that heat loss to the surroundings is negligible and thus heat transfer from the hot fluid is equal to the heat transfer to the cold fluid. **3** Changes in the kinetic and potential energies of fluid streams are negligible. **4** Fluid properties are constant.

Properties The heat of vaporization of water at 50°C is h_{fg} = 2382.0 kJ/kg and specific heat of cold water is c_p = 4.18 kJ/kg.°C (Tables A-3 and A-4).

Analysis We take the cold water tubes as the system, which is a control volume. The energy balance for this steady-flow system can be expressed in the rate form as



$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\substack{\text{Rate of net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{\Delta \dot{E}_{system}^{\nearrow 0 \text{ (steady)}}}_{\substack{\text{Rate of change in internal, kinetic,}\\ \text{potential, etc. energies}}} = 0$$

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

$$\dot{Q}_{in} + \dot{m}h_1 = \dot{m}h_2 \quad (\text{since } \Delta\text{ke} \cong \Delta\text{pe} \cong 0)$$

$$\dot{Q}_{in} = \dot{m}c_p(T_2 - T_1)$$

Then the heat transfer rate to the cooling water in the condenser becomes

$$\dot{Q} = [\dot{m}c_p(T_{out} - T_{in})]_{\text{cooling water}}$$
$$= (101\text{ kg/s})(4.18\text{ kJ/kg.°C})(27\text{°C} - 18\text{°C})$$
$$= 3800\text{ kJ/s}$$

The rate of condensation of steam is determined to be

$$\dot{Q} = (\dot{m}h_{fg})_{steam} \longrightarrow \dot{m}_{steam} = \frac{\dot{Q}}{h_{fg}} = \frac{3800\text{ kJ/s}}{2382.0\text{ kJ/kg}} = \mathbf{1.60\ kg/s}$$