SECTION I:

Question 1 (5 points):

For a single inlet / single outlet control volume in which mass is conserved:

(a) Mass flow rate into or out of the control volume is proportional to the normal component of the flow velocity.
(b) Mass can accumulate inside the control volume during steady state.
(c) Velocity during the steady flow of an incompressible fluid is inversely proportional to the area.
~~(d) (a) only.~~
(e) (b) and (c) only.
(f) (a) and (c) only.
(g) (a), (b), and (c).

Question 2 (5 points):

Which of the following is **true** during a steady state flow:

(a) It is possible for the properties inside the control volume to be non-uniform in space.
(b) It is possible for the properties inside the control volume to change with time.
(c) Total energy inside the control volume can decrease.
(d) Total energy inside the control volume can increase.
(e) None of the above.

Question 3 (5 points):

Which of the following statements is **true** when an ideal gas is throttled (assuming a steady state process):

(a) Specific enthalpy remains constant.
(b) Temperature remains constant.
(c) Pressure decreases.
(d) All of the above.

Question 4 (5 points):

Which of the following statements is **true**:

(a) For a cyclic process $\Delta U = 0$.
(b) A process that violates the second law of thermodynamics, could still satisfy the first law of thermodynamics.
(c) Quality of energy degrades when stored in a lower temperature reservoir.
(d) All of the above.
(e) None of the above.

Question 5 (5 points):

Which of the following statements is **false**:

(a) A process that goes through a series of equilibrium states is reversible.
(b) The second law does not limit how much of the work can be converted to heat.
(c) Heat transfer through a finite temperature difference is irreversible.
(d) All of the above.
(e) None of the above.

Question 6 (5 points):

Which of the following statements is **true**:

(a) A reversible heat engine can have 100% efficiency.
(b) Engine efficiency depends on the type of the working fluid.
(c) It is possible to have $Q_H = Q_L$ for a heat engine.
(d) It is possible to have $Q_H = Q_L$ for a refrigerator.
(e) The coefficient of performance of a heat pump can be > 1.
(f) All of the above.
(g) (a) and (b) only.
(h) (c) and (e) only.
(i) (d) and (e) only.
(j) (a), (c) and (e) only.
(k) (a), (d), and (e) only.

Question 7:

Steady state. 2 inlets, 1 outlet. $Q = \Delta K.E = \Delta P.E = 0$

Exit State: $P_3 = 300\ kPa$, Sat. liquid $\} \Rightarrow T_3 = T_{sat} @ 300\ kPa = 133.55\ °C$

Mass Balance: $\dot{m}_3 = \dot{m}_1 + \dot{m}_2$

Energy Eqn: $\frac{dE}{dt} = 0 = \dot{Q}^{\nearrow 0} - \dot{W}^{\nearrow 0} + \sum_i \dot{m}_i h_i - \sum_e \dot{m}_e h_e$

$\Rightarrow \dot{m}_1 h_1 + \dot{m}_2 h_2 - \dot{m}_3 h_3 = 0$

State at inlet 1: $P_1 = 300\ kPa$, $T_1 = 45°C$, comp. liquid $\} \quad h_1 \approx h_{f@45°C} = 188.42\ kJ/kg$

State at inlet 2: $P_2 = 300\ kPa$, $T_2 = 300°C$, water vapor $\} \quad h_2 = 3069.28\ kJ/kg$

State at exit 3: $P_3 = 300\ kPa$, $T_3 = 133.55°C$, Sat. liq. $\} \quad h_3 = h_f = 561.45\ kJ/kg$

$$\dot{m}_2 = \frac{\dot{m}_1 (h_3 - h_1)}{h_2 - h_3}$$

$\Uparrow$

$\dot{m}_1 h_1 + \dot{m}_2 h_2 - (\dot{m}_1 + \dot{m}_2) h_3 = 0$

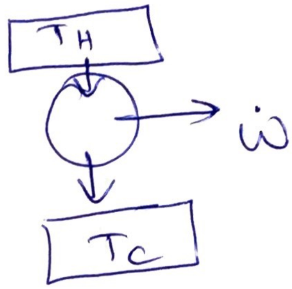
$\Rightarrow \dot{m}_1 h_1 + \dot{m}_2 h_2 - \dot{m}_1 h_3 - \dot{m}_2 h_3 = 0$

$\Rightarrow \dot{m}_2 (h_2 - h_3) = \dot{m}_1 (h_3 - h_1)$

$$\Rightarrow \dot{m}_2 = 2.8 \times 10^5 \ \frac{kg}{h} \left(\frac{561.45 - 188.42}{3069.28 - 561.45} \right)$$

$$= 4.16 \times 10^4 \ kg/h$$

Question 8:



Steady state.

$\dot{W} = 10\ kW$

$\dot{Q}_H = 10\ kJ/cycle$

100 cycles / min.

$T_C = T_L = 300\ K$

Energy Equation: $\dot{Q}_C = \dot{Q}_H - \dot{W}$

$$= 10\ \frac{kJ}{cycle} \times 100\ \frac{cycles}{min} \times \frac{1 min}{60 sec} - 10 kW$$

$$= 16.67\ kW - 10\ kW = 6.67\ kW$$

$$\eta = 1 - \frac{\dot{Q}_C}{\dot{Q}_H}$$

$\Rightarrow$ min possible T_H occurs when $\eta = \eta_{max}$

$$\eta = \eta_{max} = \eta_{carnot} = 1 - \frac{T_L}{T_H}$$

$$\Rightarrow 1 - \frac{\dot{Q}_C}{\dot{Q}_H} = 1 - \frac{T_L}{T_H} \Rightarrow \frac{\dot{Q}_C}{\dot{Q}_H} = \frac{T_L}{T_H}$$

$$\Rightarrow T_{H\,min} = T_L \left(\frac{\dot{Q}_H}{\dot{Q}_C}\right) = (300\ K)\left(\frac{16.67}{6.67}\right)$$

$$= 750\ K$$

$$\eta_{rev} = 1 - \frac{T_L}{T_{H min}} = 1 - \frac{300}{750} = 60\ \%$$

Question 9:

Transient process

$W = \Delta K.E. = \Delta P.E. = 0$

C.V. = tank

State 1: $T_1 = 200°C$, sat. liquid $\Big\}$ $v_1 = v_{f@200°C} = 0.001156\ m^3/kg$
$u_1 = u_{f@200°C} = 850.64\ kJ/kg$

Exit State: $T_e = 200°C$, sat. liquid $\Big\}$ $h_e = h_{f@200°C} = 852.43\ kJ/kg$

Mass balance: $\Delta m_{C.V.} = m_{in} - m_{out} = -m_e$

$\Rightarrow m_1 - m_2 = m_e$

Energy Equation: $\Delta E_{C.V.} = E_2 - E_1 = m_2 u_2 - m_1 u_1$
$= Q_{in} - m_e h_e$

$$m_1 = \frac{V_1}{v_1} = \frac{0.3\ m^3}{0.001156\ m^3/kg} = 259.5\ kg$$

$$m_2 = \frac{1}{2} m_1 = 129.75\ kg$$

$$\Rightarrow m_e = m_1 - m_2 = 129.75\ kg$$

$$v_2 = \frac{V}{m_2} = \frac{0.3\ m^3}{129.75\ kg} = 0.002312\ m^3/kg$$

$T_2 = 200°C$ $\Big\}$ $\Rightarrow$ 2-phase

$$x_2 = \frac{v_2 - v_f}{v_{fg}} = \frac{0.002312 - 0.001156}{0.12620} = 0.00916$$

$T_2 = 200°C$
$x_2 = 0.00916$ } $u_2 = u_f + x_2 u_{fg}$

$= 850.64 + (0.00916)(1744.66)$

$= 866.62$ kJ/kg

$\Rightarrow Q_{in} = m_2 u_2 - m_1 u_1 + m_e h_e$

$= (129.75)(866.62) - (259.5)(850.64)$
$+ (129.75)(852.43)$

$= 2305.7$ kJ