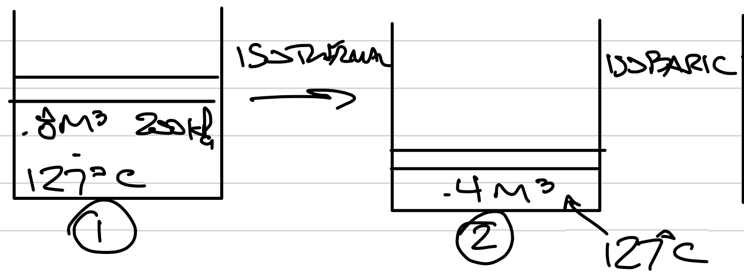
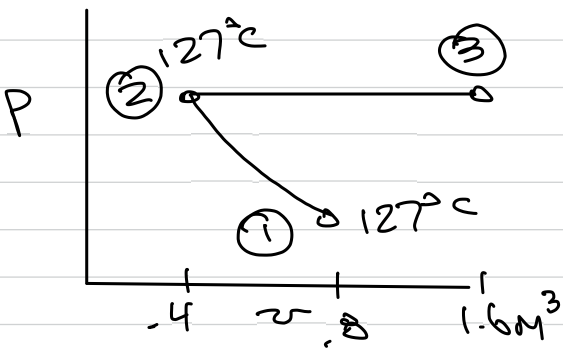
AIR IN A PISTON CYLINDER DEVICE AT AN INITIAL STATE OF 127°C, 200 kPa : 0.8 m³ IS COMPRESSED ISOTHERMALLY TO 0.4 m³ THEN EXPANDED AT CONSTANT PRESSURE TO 1.6 m³. FIND THE TOTAL HEAT TRANSFER AND DIRECTION. DRAW THE SYSTEM AND SHOW THE PROCESS ON A Pv DIAGRAM FROM STATE 1 TO 2 TO 3



3 STEP PROCESS

5



Pv OR Tv

5

ENERGY EQUATION

10

$$Q - W = \Delta E_{sys}$$

$$Q - W_{1\to 2} - W_{2\to 3} = \Delta E_{sys}$$

WORK EQUATIONS

10

$$Q - \int_1^2 P\,dV - \int_2^3 P\,dV = \Delta E_{sys}$$

$$Q - mRT\int \frac{1}{V}\,dV - P\int_2^3 dV = mC_v(T_3 - T_1)$$

$$Q - mRT\ln\frac{V_2}{V_1} - P(V_3 - V_2) = mC_v(T_3 - T_1)$$

$$Q - mRT_1 \ln\frac{V_2}{V_1} - P(V_3 - V_2) = mC_v(T_3 - T_1)$$

$$Q = m_1 R T_1 \ln \frac{V_2}{V_1} - P_2(V_3 - V_2) + m_1 C_{v_{AVE}}(T_3 - T_1)$$

$$m = \frac{P_1 V_1}{R T_1} = \frac{(200\,kPa)(0.8\,m^3)}{(8.314/29)(400\,K)} = 1.394\,kg$$

5 MASS

ISOTHERMAL

$$P_2 = P_1 \frac{V_1}{V_2} = 200\,kPa \,\frac{0.8\,m^3}{0.4\,m^3} = 400\,kPa$$

ISOBARIC

$$T_3 = T_2 \frac{V_3}{V_2} = 400\,K \,\frac{1.6\,m^3}{0.4\,m^3} = 1600\,K$$

$C_{v_{AVE}}$ @ $T_{AVE} = \frac{T_3 + T_2}{2} = \frac{1600\,K + 400\,K}{2} = 1000\,K$

$C_{v_{AVE}} = 0.855\ kJ/kg\,K$

10 P, T, Cv

$Q = 1.394\,kg\,(0.855)(400\,K) \ln\frac{0.4}{0.8}$ + [$W_{1\to2}$]

$400\,kPa\,(1.6\,m^3 - 0.4\,m^3)$ + [$W_{3\to4}$]

$1.394\,(0.287)(1600 - 400)$ [$mC_v\Delta T$]

$= -110.9\ kJ + 480\ kJ + 1430\ kJ$ or 1410 using ΔU in tables

$= 1799\ kJ$

5 FINAL ANSWER

or 1779 using ΔU OR

$-110 \qquad\qquad 1910 \text{ kJ}$

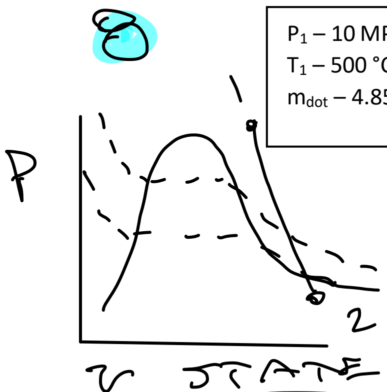
$$Q_{in} = W_{1\to2} + m C_{p_{AVE}} (T_3 - T_2)$$

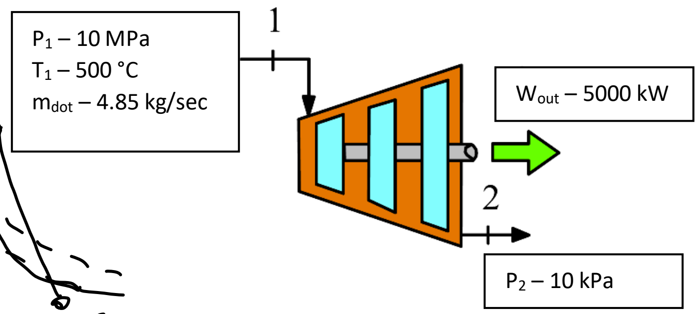
$$= -110 + 1.394 \left(1.142 \frac{kJ}{kg\,K}\right)(1600-400)$$

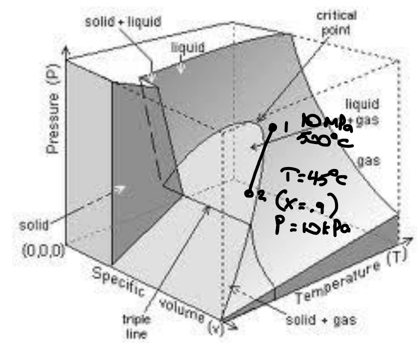
$$= 1800 \text{ kJ}$$

2. A steam turbine with an inlet flow of steam at 4.85 kg/sec, 500 °C, and 10 MPa does 5000 kW of work. The steam exits at 10 kPa. Kinetic and potential energy changes are negligible. Find the exit temperature of the steam and quality if saturated. Draw the process on the diagram below and on a two-dimensional projection of the diagram below.

8







5

STATE 1

10 MPa
500°C
4.85 kg/s

$h_1 = 3375.1 \frac{kJ}{kg}$ 5 ✓

SUPERHEATED 2 ✓

STATE 2

10 kPa
4.85 kg/s 5 ✓

ENERGY EQUATION

✓ $\dot{m}_1 h_1 = W_{out} + \dot{m}_2 h_2$

MASS CONTINUITY

$\dot{m}_1 = \dot{m}_2$ 3 ✓

5 $h_2 = h_1 - \frac{W_{out}}{\dot{m}} = 3375 \frac{kJ}{kg} - \frac{5000 \; kJ/s}{4.85 \; kg/s} = 2344 \frac{kJ}{kg}$

@ 10 kPa 2344 kJ/kg is SAT. VAPOR 2 ✓

5 ✓ $h_2 = 2344 \frac{kJ}{kg} = h_f + x(h_{fg}) = 192 \frac{kJ}{kg} + x\left(2392 \frac{kJ}{kg}\right)$

5 ✓ $x = 0.9$

5 T_{SAT} @ 10 kPa $= 45.8°C$