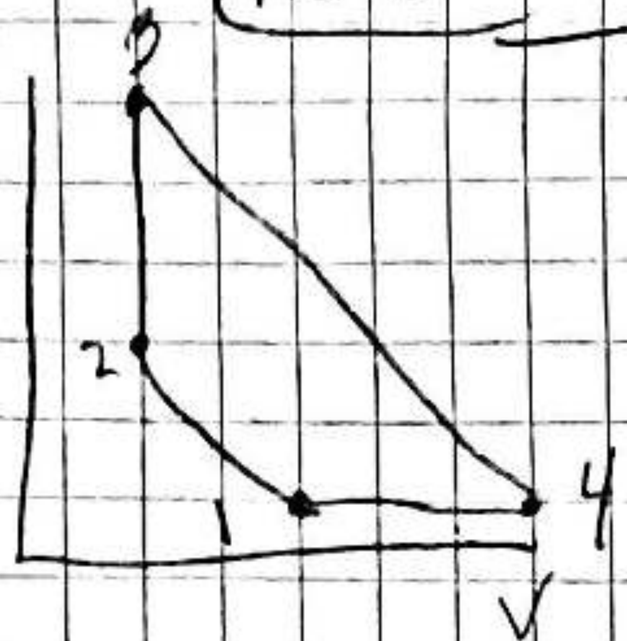
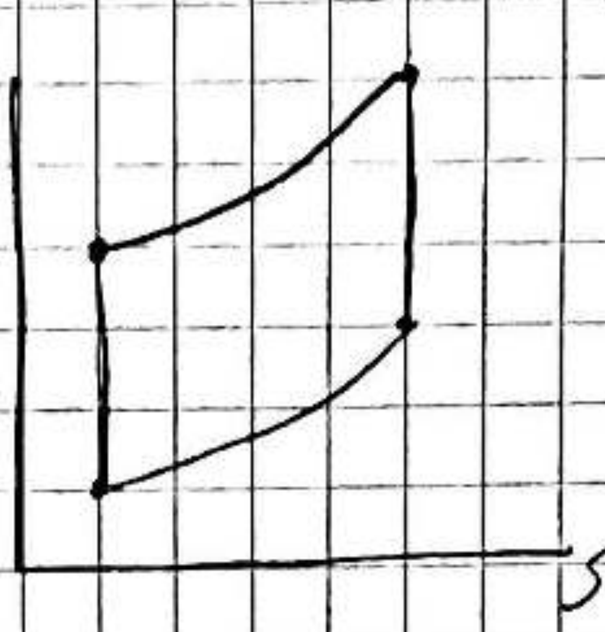
ROY SHEPARD 13, 18, 22, 31 HW 1.2

Problem 13

(A)



P-V DIAGRAM



T-S DIAGRAM

1-2 100 KPA and 22°C to 600 KPA

2-3 V = 1500K

3-4 expansion to 100 KPA

4-1 P = Heat Rejected

(B) See A17

$h_1 = 295.17 \frac{KJ}{KG}$ $P_{r2} = \frac{P_2}{P_1} P_{r1} = \frac{600}{100} \cdot 1.3068 = 7.8408$

$P_{r1} = 1.3068$

SEE A17 USE VALUE (7.824) INSTEAD OF INTERPULATION

$U_2 = 352.0 \frac{KJ}{KG}$ INTERNAL ENERGY

$T_2 = 492.74 K$

STATE 3 INTERNAL ENERGY &

$U_3 = 1205.41 \frac{KJ}{KG}$

$P_{r3} = 601.9$

Actual Pressure @ State 3

$$P_3 = P_2 \frac{T_3}{T_2} = 600 \cdot \frac{750}{492.74} = 1824.5 \text{ kPa}$$

Relative Pressure @ State 4

$$P_{r4} = \frac{P_4}{P_3} \cdot P_{r3} = \frac{100}{1826.5} \cdot 601.5 = 32.96$$

Using TABLE A-17 $32.96 \simeq 33.72$

$$h_4 = 745.62 \frac{kJ}{kg}$$

Net work

$$W = q_{IN} - q_{out} = \Delta u_{3-2} - (-\Delta h_{4-1})$$

$$u_3 - u_2 - (h_4 - h_1)$$

$$(1205.41 - 352.08 - (745.62 - 295.17)$$

$$= 402.88 \frac{kJ}{kg}$$

$$\eta = \frac{w}{q_{in}} = \frac{w}{u_3 - u_2} = \frac{402.88}{1205.41 - 352.08} = \boxed{0.472 \text{ or } 47.2\%}$$

Problem 18

Carnot Cycle

limits 350K & 1200K

pressures 150 kPa & 300 kPa

Network per Cycle 0.5 kJ

(a) Table A-17

$$P_1 = P_4 \frac{P_{r1}}{P_{r4}} = 300 \cdot \frac{238}{2.379} = \boxed{30 \text{ kPa}}$$

(b) $$\eta = 1 - \frac{T_L}{T_H} = \frac{W_{net}}{Q_{in}} = 1 - \frac{T_L}{T_H}$$

$$Q_{in} = \frac{T_H W_{net}}{T_H - T_L} = \frac{1200 \cdot 0.5}{1200 - 350} = \boxed{0.706 \text{ kJ}}$$

(c) $$m = \frac{W}{2w} = \frac{W}{(s_1 - s_4)(T_H - T_L)} = \frac{W}{(s_4 - s_3)(T_H - T_L)}$$

$$= \frac{W}{\left(s_4 - s_3 - R \ln \frac{P_4}{P_3}\right)(T_H - T_L)} = \frac{W}{R \ln \frac{P_4}{P_3}(T_H - T_L)}$$

$$= \frac{0.5}{0.287 \ln \frac{300}{150}(1200 - 350)} = \boxed{0.00296 \text{ kg}}$$

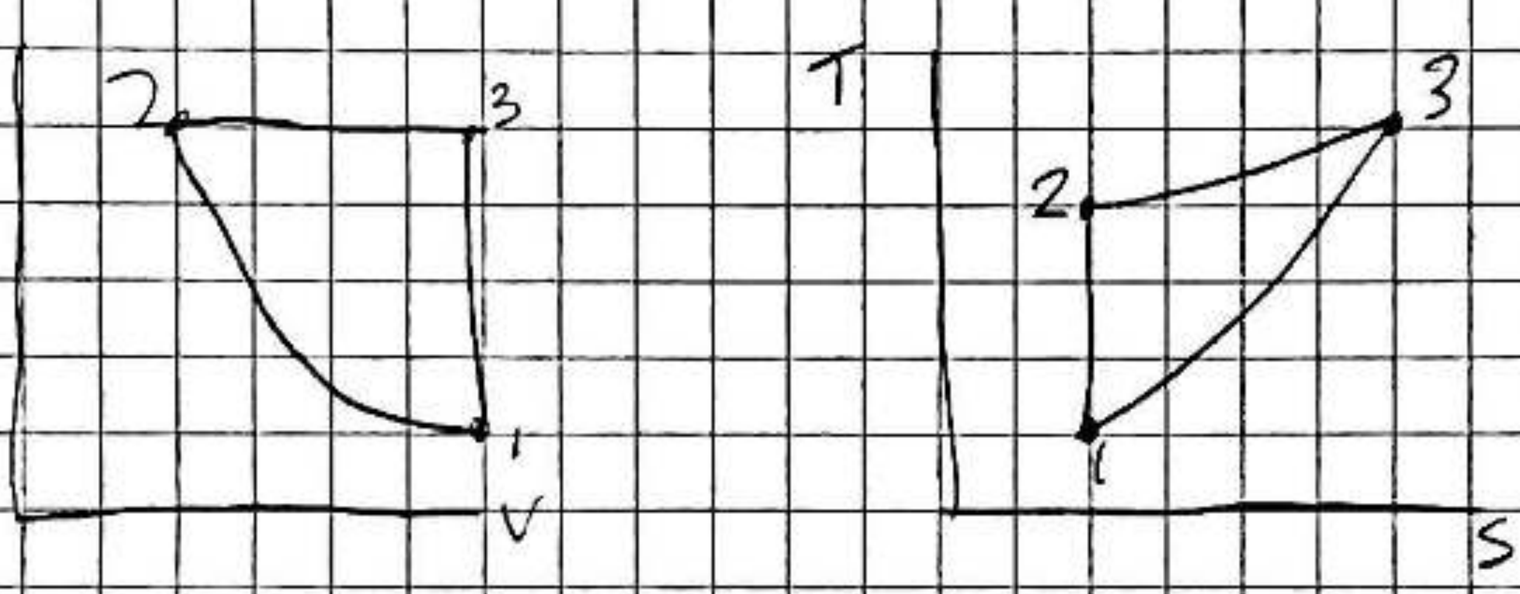
Problem 22

1-2 Isentropic compression $T_1 = 20^\circ C$ $r = 5$

2-3 constant pressure heat addition

3-1 Constant volume heat rejection

$C_V = 0.7\ kJ/kg\cdot K$ $R = 0.3\ kJ/kg\cdot K$



Heat addition 2-3

$$q_{2-3} = w_{2-3} + \Delta u_{2-3} = \Delta h_{2-3}$$

$$= C_P(T_3 - T_2) = C_P(T_2 r - T_2) = C_P T_2 (r-1)$$

$$= (R + C_V) T_1 r^{R/C_V} (r-1) = (0.3 + 0.7) \cdot 293 \cdot 5^{0.3/0.7} (5-1) \frac{kJ}{kg}$$

$$= 1233.1 \frac{kJ}{kg}$$

Heat loss 3-1

$$q_{3-1} = -\Delta u_{3-1}$$

$$= -C_V(T_1 - T_3) = -C_V(T_1 - T_2 r) = -C_V(T_1 - T_1 r^{\kappa})$$

$$= -C_V T_1 (1 - r^{R/C_V + 1}) = -0.7 \cdot 293 \left(1 - 5^{0.3/0.7 + 1}\right) \frac{kJ}{kg}$$

$$1639 \frac{kJ}{kg}$$

Part B

$$w_{1-2} = \Delta U_{1-2} = U_2 - U_1 = c_v (T_2 - T_1) =$$

$$c_v (T_1 r^{k-1} - T_1) = c_v T_1 (r^{c_p/c_v - 1} - 1) =$$

$$c_v T_1 (r^{c_p/c_v - 1}) = 0.7 \cdot 293 (5^{0.3/0.7} - 1) \frac{kJ}{kg}$$

$$= \boxed{203.7 \frac{kJ}{kg}}$$

Part C

$$w_{2-3} = p(v_3 - v_2) = R(T_3 - T_2) = R(T_{2r} - T_2)$$

$$= R T_2 (r - 1) = R T_1 r^{k-1} (r - 1) = R T_1 r^{R/c_v} (r - 1)$$

$$= 0.3 \cdot 293 \cdot 5^{0.3/0.7} (5 - 1) \frac{kJ}{kg} = 700.8 \frac{kJ}{kg}$$

$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{q_4 - 1}{q_2 - 3} =$$

$$1 - \frac{c_v (r^{R/c_v + 1} - 1)}{(R + c_v)(r - 1) r^{R/c_v}} = \frac{0.7 (5^{0.3/0.7 + 1} - 1)}{(0.3 + 0.7)(5 - 1)(5^{0.3/0.7})}$$

$$= \boxed{0.213}$$

Part D

$$\eta_{th} = 1 - \frac{r^k - 1}{k (r - 1) r^{k-1}}$$

Problem 31

$r = 10.5$ $\quad P_1 = 90 kPa$ $\quad T_1 = 40^\circ = 313K$

$W = 90 kW$ $\quad$ TABLE A-2 $\quad k = 1.4$

$$\eta = 1 - \frac{1}{r^{k-1}} = 1 - r^{1-k} = 1 - 10.5^{1-1.4}$$

$$\boxed{\eta = 0.61}$$

$$\eta = \frac{W}{Q_{in}} \quad \therefore \quad Q_{in} = \frac{W}{\eta} = \frac{90 kW}{0.61}$$

$$\boxed{Q_{in} = 147.5}$$