Question No. (4) (20 Points)

Refrigerant -134a - enters the compressor of a refrigerator as super- heated vapor at 0.14 MPa and (-10°C) at a rate of 0.12 kg/s. and it leaves at 0.7 MPa and 50°C The refrigerant is cooled in the condenser to 24°C and 0.65 MPa. And it is throttled to 0.15 MPa. Disregarding any heat transfer and pressure drops in the connecting lines between the components, **show** the cycle on a T-s diagram with respect to saturation lines, and **determine**:-

(a) The rate of heat removal from the refrigerated space and the power input to the compressor.

(b) The adiabatic efficiency of the compressor,

(c) The COP of the refrigerator.

Question No. (5) (20 Points)

(A) Consider a simple ideal Rankine cycle with fixed turbine inlet conditions. What is the effect of lowering the condenser pressure on:

(1) Pump work input:
 (a) increases, (b) decreases, (c) remains the same
(2) Turbine work output:
 (a) increases, (b) decreases, (c) remains the same
(3) Heat added:
 (a) increases, (b) decreases, (c) remains the same
(4) Heat rejected:
 (a) increases, (b) decreases, (c) remains the same
(5) Cycle efficiency:
 (a) increases, (b) decreases, (c) remains the same

(B) A steam power plant operates on a simple ideal Rankine cycle between the pressure limits of 3 MPa and 50 kPa. The temperature of the steam at the turbine inlet is 400°C. and the mass flow rate of steam through the cycle is 25 kg/s. **Show** the cycle on a T-S diagram with respect to saturation lines, and **determine**

(a) the thermal efficiency of the cycle and

(b) The net power output of the power plant.

Good Luck

السؤال الاول

[redacted] The Ideal Otto Cycle اجابة السؤال الاول

An ideal Otto cycle has a compression ratio of 8. At the beginning of the compression process, air is at 100 kPa and 17°C, and 800 kJ/kg of heat is transferred to air during the constant-volume heat-addition process. Accounting for the variation of specific heats of air with temperature, determine (*a*) the maximum temperature and pressure that occur during the cycle, (*b*) the net work output, (*c*) the thermal efficiency, and (*d*) the mean effective pressure for the cycle.

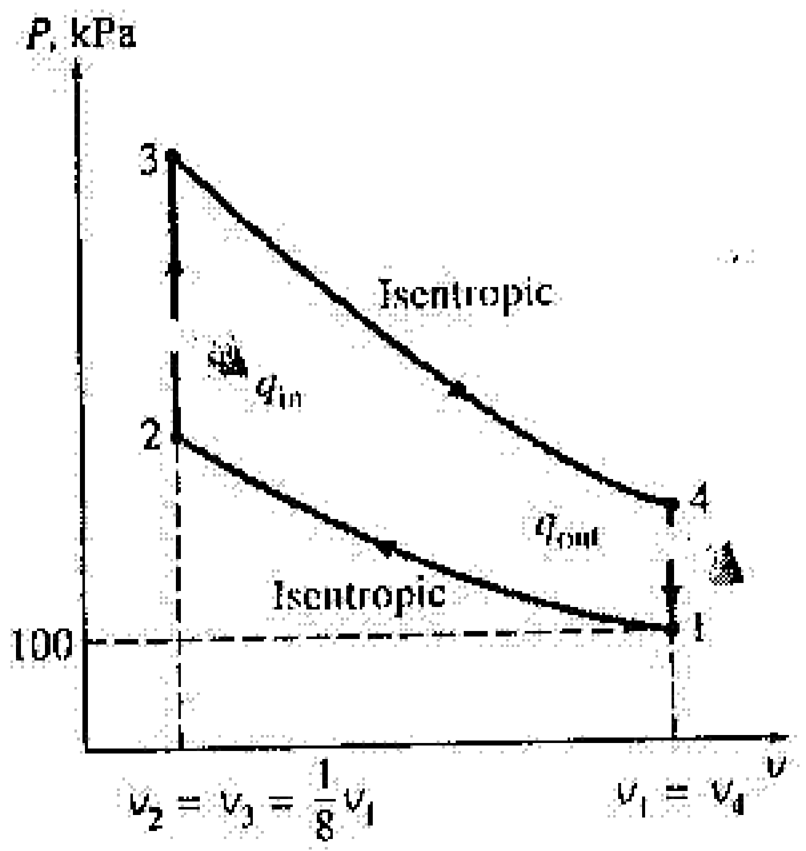


FIGURE 9–19

P-v diagram for the Otto cycle discussed in Example 9–2.

Solution An ideal Otto cycle is considered. The maximum temperature and pressure, the net work output, the thermal efficiency, and the mean effective pressure are to be determined.

Assumptions **1** The air-standard assumptions are applicable. **2** Kinetic and potential energy changes are negligible. **3** The variation of specific heats with temperature is to be accounted for.

Analysis The *P-v* diagram of the ideal Otto cycle described is shown in Fig. 9–19. We note that the air contained in the cylinder forms a closed system.

(*a*) The maximum temperature and pressure in an Otto cycle occur at the end of the constant-volume heat-addition process (state 3). But first we need to determine the temperature and pressure of air at the end of the isentropic compression process (state 2), using data from Table A–17:

$$T_1 = 290\ \text{K} \rightarrow u_1 = 206.91\ \text{kJ/kg}$$
$$v_{r1} = 676.1$$

Process 1-2 (isentropic compression of an ideal gas):

$$\frac{v_{r2}}{v_{r1}} = \frac{v_2}{v_1} = \frac{1}{r} \rightarrow v_{r2} = \frac{v_{r1}}{r} = \frac{676.1}{8} = 84.51 \rightarrow T_2 = 652.4\ \text{K}$$
$$u_2 = 475.11\ \text{kJ/kg}$$

$$\frac{P_2 v_2}{T_2} = \frac{P_1 v_1}{T_1} \rightarrow P_2 = P_1\left(\frac{T_2}{T_1}\right)\left(\frac{v_1}{v_2}\right)$$
$$= (100\ \text{kPa})\left(\frac{652.4\ \text{K}}{290\ \text{K}}\right)(8) = 1799.7\ \text{kPa}$$

Process 2-3 (constant-volume heat addition):

$$q_{in} = u_3 - u_2$$
$$800\ \text{kJ/kg} = u_3 - 475.11\ \text{kJ/kg}$$
$$u_3 = 1275.11\ \text{kJ/kg} \rightarrow \boxed{T_3 = 1575.1\ \text{K}}$$
$$v_{r3} = 6.108$$

تابع إجابة السؤال الأول

$$\frac{P_3 v_3}{T_3} = \frac{P_2 v_2}{T_2} \rightarrow P_3 = P_2\left(\frac{T_3}{T_2}\right)\left(\frac{v_2}{v_3}\right)$$

$$= (1.7997\text{ MPa})\left(\frac{1575.1\text{ K}}{652.4\text{ K}}\right)(1) = \boxed{4.345\text{ MPa}}$$

(*b*) The net work output for the cycle is determined either by finding the boundary ($P\,dV$) work involved in each process by integration and adding them or by finding the net heat transfer that is equivalent to the net work done during the cycle. We take the latter approach. However, first we need to find the internal energy of the air at state 4:

Process 3-4 (isentropic expansion of an ideal gas):

$$\frac{v_{r4}}{v_{r3}} = \frac{v_4}{v_3} = r \rightarrow v_{r4} = r v_{r3} = (8)(6.108) = 48.864 \rightarrow T_4 = 795.6\text{ K}$$

$$u_4 = 588.74\text{ kJ/kg}$$

Process 4-1 (constant-volume heat rejection):

$$-q_{\text{out}} = u_1 - u_4 \rightarrow q_{\text{out}} = u_4 - u_1$$

$$q_{\text{out}} = 588.74 - 206.91 = 381.83\text{ kJ/kg}$$

Thus,

$$w_{\text{net}} = q_{\text{net}} = q_{\text{in}} - q_{\text{out}} = 800 - 381.83 = \boxed{418.17\text{ kJ/kg}}$$

(*c*) The thermal efficiency of the cycle is determined from its definition:

$$\eta_{\text{th}} = \frac{w_{\text{net}}}{q_{\text{in}}} = \frac{418.17\text{ kJ/kg}}{800\text{ kJ/kg}} = \boxed{0.523\text{ or }52.3\%}$$

Under the cold-air-standard assumptions (constant specific heat values at room temperature), the thermal efficiency would be (Eq. 9–8)

$$\eta_{\text{th,Otto}} = 1 - \frac{1}{r^{k-1}} = 1 - r^{1-k} = 1 - (8)^{1-1.4} = 0.565\text{ or }56.5\%$$

which is considerably different from the value obtained above. Therefore, care should be exercised in utilizing the cold-air-standard assumptions.

(*d*) The mean effective pressure is determined from its definition, Eq. 9–4:

$$\text{MEP} = \frac{w_{\text{net}}}{v_1 - v_2} = \frac{w_{\text{net}}}{v_1 - v_1/r} = \frac{w_{\text{net}}}{v_1(1 - 1/r)}$$

where

$$v_1 = \frac{RT_1}{P_1} = \frac{(0.287\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(290\text{ K})}{100\text{ kPa}} = 0.832\text{ m}^3/\text{kg}$$

Thus,

$$\text{MEP} = \frac{418.17\text{ kJ/kg}}{(0.832\text{ m}^3/\text{kg})\left(1 - \frac{1}{8}\right)}\left(\frac{1\text{ kPa}\cdot\text{m}^3}{1\text{ kJ}}\right) = \boxed{574\text{ kPa}}$$

Discussion Note that a constant pressure of 574 kPa during the power stroke would produce the same net work output as the entire cycle.

إجابة السؤال الثانى _ (٩)

dard assumptions becomes

$$\eta_{\text{th,Otto}} = \frac{w_{\text{net}}}{q_{\text{in}}} = 1 - \frac{q_{\text{out}}}{q_{\text{in}}} = 1 - \frac{T_4 - T_1}{T_3 - T_2} = 1 - \frac{T_1(T_4/T_1 - 1)}{T_2(T_3/T_2 - 1)}$$

Processes 1-2 and 3-4 are isentropic, and $v_2 = v_3$ and $v_4 = v_1$. Thus,

$$\frac{T_1}{T_2} = \left(\frac{v_2}{v_1}\right)^{k-1} = \left(\frac{v_3}{v_4}\right)^{k-1} = \frac{T_4}{T_3} \qquad (9\text{–}7)$$

Substituting these equations into the thermal efficiency relation and simplifying give

$$\eta_{\text{th,Otto}} = 1 - \frac{1}{r^{k-1}} \qquad (9\text{–}8)$$

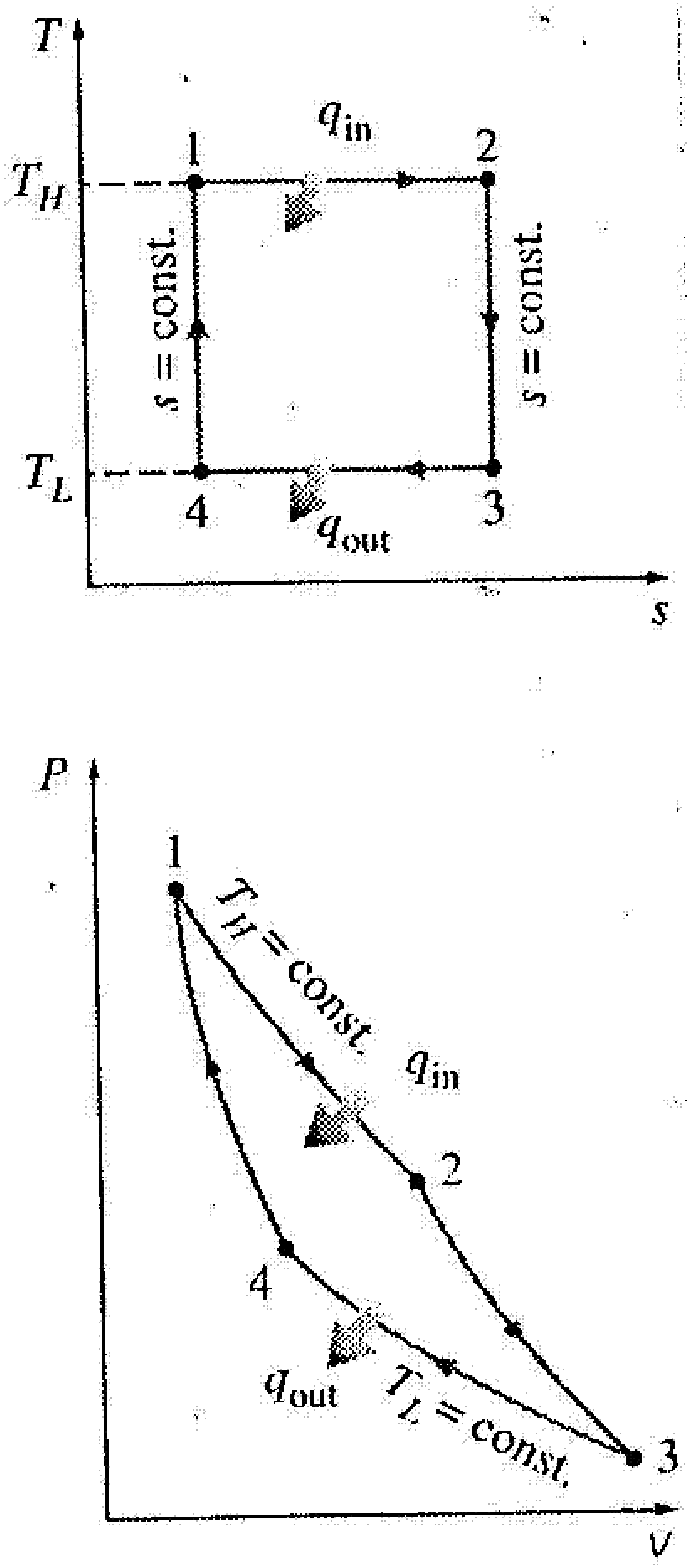
where

$$r = \frac{V_{\text{max}}}{V_{\text{min}}} = \frac{V_1}{V_2} = \frac{v_1}{v_2} \qquad (9\text{–}9)$$

is the **compression ratio** and k is the specific heat ratio c_p/c_v.

Equation 9–8 shows that under the cold-air-standard assumptions, the thermal efficiency of an ideal Otto cycle depends on the compression ratio of the engine and the specific heat ratio of the working fluid. The thermal efficiency of the ideal Otto cycle increases with both the compression ratio

إجابة السؤال الثانى (b)



(*a*) Carnot cycle

إجابة لسؤال الثاني (ج)

جيد

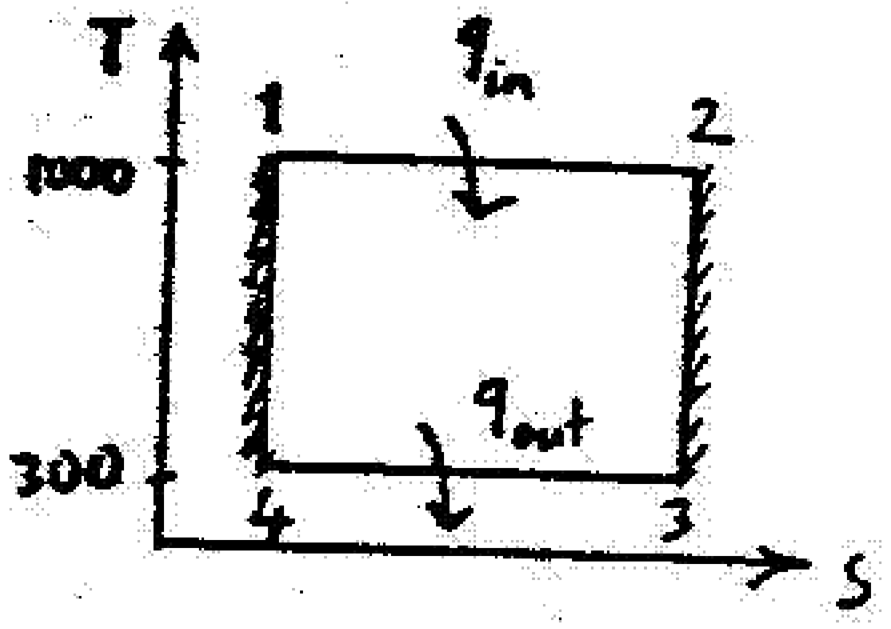
الحل

~~8-74~~ We treat air as an ideal gas with constant specific heats at room temperature, $C_p = 1.005$ and $C_v = 0.718$ kJ/kg.K, and $k = 1.4$. The minimum pressure in the cycle is P3 and the maximum pressure is P1. Then,

$$\frac{T_2}{T_3} = \left(\frac{P_2}{P_3}\right)^{(k-1)/k}$$

or,

$$P_2 = P_3\left(\frac{T_2}{T_3}\right)^{k/(k-1)} = (20\text{ kPa})\left(\frac{1000\text{ K}}{300\text{ K}}\right)^{1.4/0.4} = \boxed{1352\text{ kPa}}$$



The heat input is determined from

$$s_2 - s_1 = \underbrace{C_p \ln\frac{T_2}{T_1}}_{\nearrow 0} - R\ln\frac{P_2}{P_1} = -(0.287\text{ kJ/kg.K})\ln\frac{1352\text{ kPa}}{1800\text{ kPa}}$$

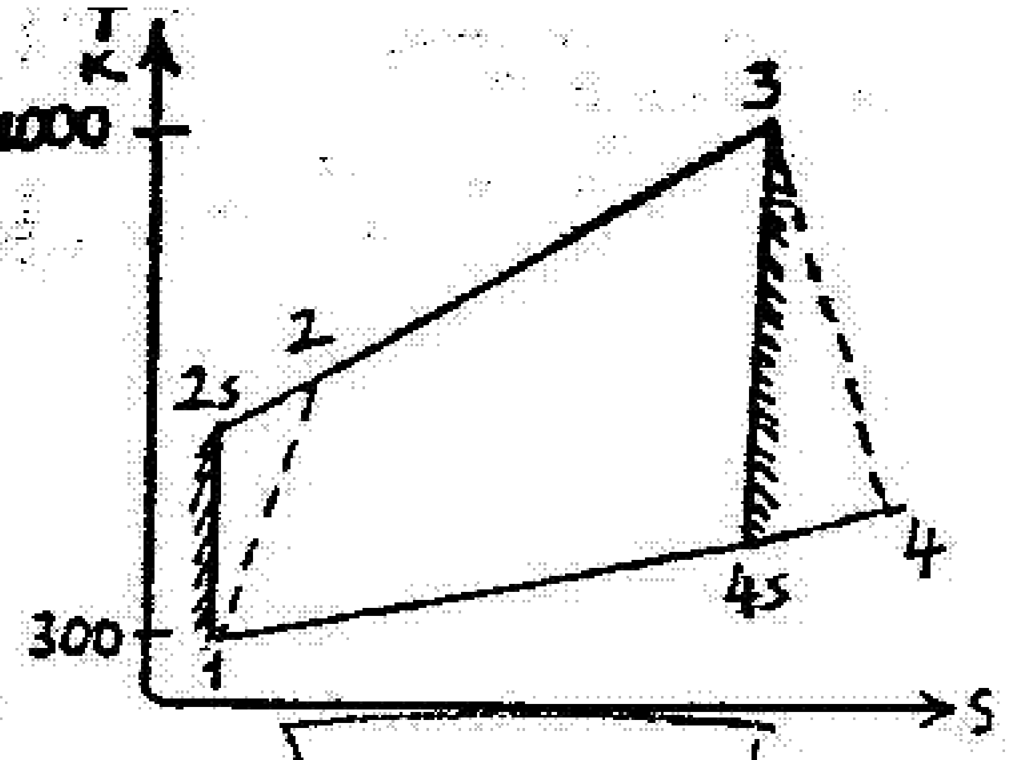
$$= \boxed{0.08205\text{ kJ/kg.K}}$$

$$Q_{in} = mT_H(s_2 - s_1) = (0.004\text{ kg})(1000\text{ K})(0.08205\text{ kJ/kg.K}) = 0.328\text{ kJ}$$

$$\eta_{th} = 1 - \frac{T_L}{T_H} = 1 - \frac{300\text{ K}}{1000\text{ K}} = \boxed{70.0\%}$$

$$W_{net} = \eta_{th}Q_{in} = 0.70(0.328\text{ kJ}) = \boxed{0.230\text{ kJ}}$$

إجابة السؤال الثالث



~~8-77~~ (a) Air at specified conditions can be treated as an ideal gas with constant specific heats. Then,

$$\boxed{T_{2s}} = T_1\left(\frac{P_2}{P_1}\right)^{(k-1)/k} = (300\ \text{K})(12)^{0.4/1.4} = \boxed{610.2\ \text{K}}$$

$$\boxed{T_{4s}} = T_3\left(\frac{P_4}{P_3}\right)^{(k-1)/k} = (1000\ \text{K})\left(\frac{1}{12}\right)^{0.4/1.4} = \boxed{491.7\ \text{K}}$$

$$\boxed{w_{s,C,in}} = h_{2s} - h_1 = C_p(T_{2s} - T_1) = (1.005\ \text{kJ/kg.K})(610.2 - 300)\text{K} = \boxed{311.75\ \text{kJ/kg}}$$

$$\boxed{w_{s,T,out}} = h_{3s} - h_4 = C_p(T_3 - T_{4s}) = (1.005\ \text{kJ/kg.K})(1000 - 491.7)\text{K} = \boxed{510.84\ \text{kJ/kg}}$$

$$\boxed{w_{s,net}} = w_{s,T,out} - w_{s,C,in} = 510.84 - 311.75 = \boxed{199.09\ \text{kJ/kg}}$$

$$\boxed{\dot{m}_s} = \frac{\dot{W}_{net}}{w_{s,net}} = \frac{30{,}000\ \text{kJ/s}}{199.09\ \text{kJ/kg}} = \boxed{150.7\ \text{kg/s}}$$

(b) Assuming $\eta_C = \eta_T = 80\%$,

$$w_{a,net} = w_{a,T,out} - w_{a,C,in} = \eta_T w_{s,T,out} - w_{s,C,in}/\eta_C$$

$$= 0.80 \times 510.84 - 311.75/0.80 = 18.98\ \text{kJ/kg}$$

$$\boxed{\dot{m}_a} = \frac{\dot{W}_{net}}{w_{a,net}} = \frac{30{,}000\ \text{kJ/s}}{18.98\ \text{kJ/kg}} = \boxed{1581\ \text{kg/s}}$$

(a) $Q_L = \dot{m} (h_1 - h_4)$

$= 0.12 (243.4 - 82.9)$

$= 19.26$ kW

$W_{in} = \dot{m} (h_2 - h_1)$

(a) $W_{in} = 0.12 (286.35 - 243.4)$

$= 5.154$ kW

b $\eta_c = \dfrac{h_{2s} - h_1}{h_2 - h_1}$

$= \dfrac{278.06 - 243.4}{286.35 - 243.4}$

$= 80.7\ \%$

(c) $(COP)_R = \dfrac{Q_L}{W_{in}}$

$= \dfrac{19.26}{5.154}$

$= 3.74$

إجابة السؤال الخامس (A)

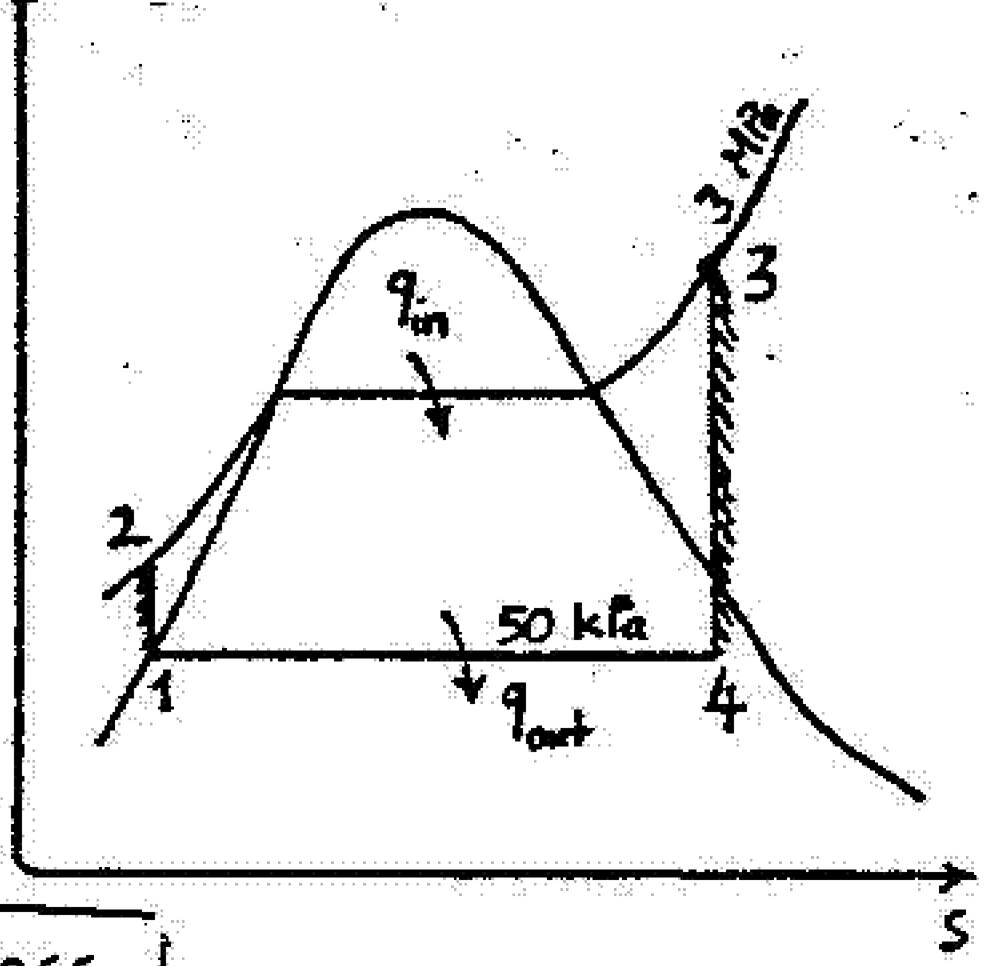
(A) Consider a simple ideal Rankine cycle with fixed turbine inlet conditions.

What is the effect of lowering the condenser pressure on:

(1) Pump work input:
    (a) increases, (b) decreases, (c) remains the same
(2) Turbine work output:
    (a) increases, (b) decreases, (c) remains the same
(3) Heat added:
    (a) increases, (b) decreases, (c) remains the same
(4) Heat rejected:
    (a) increases, (b) decreases, (c) remains the same
(5) Cycle efficiency:
    (a) increases, (b) decreases, (c) remains the same

9[illegible]5 (a) From the steam tables,

$$\boxed{h_1} = h_f\,@\,50\text{ kPa} = 340.49\text{ kJ/kg}$$
$$v_1 = v_f\,@\,50\text{ kPa} = 0.001030\text{ m}^3\text{/kg}$$



$$w_{p,in} = v_1(P_2 - P_1)$$
$$= (0.00103\text{ m}^3\text{/kg})(3000 - 50\text{ kPa})\left(\frac{1\text{ kJ}}{1\text{ kPa.m}^3}\right)$$
$$= 3.04\text{ kJ/kg}$$
$$h_2 = h_1 + w_{p,in} = 340.49 + 3.04 = 343.53\text{ kJ/kg}$$

$$\left.\begin{array}{l} P_3 = 3\text{ MPa} \\ T_3 = 400°\text{C} \end{array}\right\} \begin{array}{l} h_3 = 3230.9\text{ kJ/kg} \\ s_3 = 6.9212\text{ kJ/kg.K} \end{array}$$

$$\left.\begin{array}{l} P_4 = 50\text{ kPa} \\ s_4 = s_3 \end{array}\right\} \boxed{x_4} = \frac{s_4 - s_f}{s_{fg}} = \frac{6.9212 - 1.0910}{6.5029} = \boxed{0.8966}$$
$$h_4 = h_f + x_4 h_{fg} = 340.49 + 0.8966\times 2305.4$$
$$= 2407.5\text{ kJ/kg}$$

Thus,

$$q_{in} = h_3 - h_2 = 3230.9 - 343.53 = 2887.37\text{ kJ/kg}$$
$$q_{out} = h_4 - h_1 = 2407.5 - 340.49 = 2067.01\text{ kJ/kg}$$
$$w_{net} = q_{in} - q_{out} = 2887.37 - 2067.01 = 820.36\text{ kJ/kg}$$

and

$$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{2067.01}{2887.73} = 28.4\%$$

(b) $\dot{W}_{net} = \dot{m}\, w_{net} = (25\text{ kg/s})(820.36\text{ kJ/kg}) = 20.5\text{ MW}$

إجابة السؤال الخامس (B)

Fayoum University
Faculty of Engineering
Industrial Engineering Department

Final Exam 2nd year
Thermo Dynamics
Jan, 2010: Time: 3 Hrs

السنة الثانية – قسم الهندسة الصناعية - ديناميكا حرارية

Answer the Following Questions

Question No. (1) **(20 Points)**

An ideal Otto cycle has a compression ratio of 8. At the beginning of the compression process, the air is at 100 kpa and 17°C, and 800 kJ/ kg of heat is transferred to air during the constant volume heat addition process. Account for the variation of specific heats of air with temperature, **Determine**:-

1) The maximum temperature and pressure which occur during the cycle.
2) The net work output.
3) The thermal efficiency.
4) The mean effective pressure of the cycle.

Question No. (2) **(20 Points)**

(a) **Prove** that Otto efficiency = 1- (1 / (r^{k-1}))

(b) **Draw** the Carnot gas power cycle in (P-V) and (T-S) diagrams

(c) Consider a Carnot cycle executed in a closed system with 0.004 kg of air. The temperature limits of the cycle are 300 and 1000 K. and the minimum and maximum pressure that occur during the cycle are 20 and 1800 kPa. Assuming constant specific heats, **determine** the net work output per cycle.

Question No. (3) **(20 Points)**

Airs used the working fluid in a simple Brayton cycle which has a pressure ratio 12, a compressor inlet temperature of 300K, and a turbine inlet temperature of 1000 K. **Determine** the required mass flow rate of air for a net power output of 30 MW. Assuming both the compressor and the turbine has an isentropic efficiency of 80 percent.

Assume constant specific heals at room temperature