Detailed Solution of Quiz 1 2020-2021 Regular,
Regular Stream 2020-2021

QUIZ 1, 2020-2021- ME 365 THERMODYNAMICS II

INSTRUCTIONS

Select the correct ANSWER and place a ring around the letter corresponding to the correct answer in PEN. In questions 15, 16, 17, 18, 48 and 62- 78, you are required to show detailed working on the question paper to arrive at the answer before you select the answer.

Each question involving calculations and answered correctly will attract 2 marks each while the non-calculation questions will attract 1 mark for each correct answer.

ENTROPY

Entropy Property

1. Integral of δQ/T is independent of reversible path connecting between two points.
a) true
b) false

Fact

2. Entropy is a
a) path function, intensive property
b) path function, extensive property
c) point function, intensive property
d) point function, extensive property

Fact

3. For any process which is undergone by a system
a) δQ/T ≥ ds
b) δQ/T ≤ ds
c) δQ/T ≠ ds
d) none of the mentioned

Fact

4. For an irreversible process,
a) dS = δQ/T
b) dS > δQ/T
c) dS < δQ/T
d) none of the mentioned

Fact

5. For the general case, we can write
a) S_2-S_1 ≤ δQ/Tfor a path
b) S_2-S_1 ≥ δQ/Tfor a path
c) S_2-S_1 ≠ δQ/T for a path
d) none of the mentioned

Fact

5

Temperature Entropy Plot

6. A reversible adiabatic process is an isentropic process.
a) true
b) false

7. Which of the following statement is true?
a) for reversible isothermal heat transfer, $Q=t(S_f-S_i)$
b) for reversible adiabatic process, S=constant
c) both of the mentioned
d) none of the mentioned

8. Net Work in a Carnot cycle is given by (T_1=temperature of heat addition and T_2=temperature of heat rejection)
a) $(T_2-T_1)(S_1-S_4)$
b) $(T_1-T_2)(S_1-S_4)$
c) $(T_1-T_2)(S_4-S_1)$
d) none of the mentioned

$$|W_{net}| = |Q_{net}| = (T_1-T_2)(S_1-S_4)$$

9. The infinitesimal change in entropy dS due to reversible heat transfer δQ at temperature T is dS = δQ/T
a) true
b) false

Entropy Principle and its Applications – 1

10. Which of the following is true?
a) for an isolated system, $dS \geq 0$
b) for a reversible process, $dS = 0$
c) for an irreversible process, $dS > 0$
d) all of the mentioned

11. Entropy may decrease locally at some region within the isolated system. How can this statement be justified?
a) this cannot be possible
b) this is possible because entropy of an isolated system can decrease.
c) it must be compensated by a greater increase of entropy somewhere within the system.
d) none of the mentioned

12. The entropy of an isolated system always ____ and becomes a ____ at the state of equilibrium.
a) decreases, minimum
b) increases, maximum
c) increases, minimum
d) decreases, maximum

4

But $\eta_1 = \eta_2$

$$\Rightarrow 1 - \frac{T_m}{T_1} = 1 - \frac{T_2}{T_m}$$

13. The final temperatures of two bodies, initially at T_1 and T_2 can range from

a) $(T_1-T_2)/2$ to sqrt(T_1*T_2)

b) $(T_1+T_2)/2$ to sqrt(T_1*T_2)

c) $(T_1+T_2)/2$ to (T_1*T_2)

d) $(T_1-T_2)/2$ to (T_1*T_2)

$$\Leftrightarrow \frac{T_m}{T_1} = \frac{T_2}{T_m}$$

$$\therefore T_m^2 = T_1 T_2$$

when brought into physical contact the $T_f = \frac{T_1 + T_2}{2}$

when form a heat engine cycle is series

$\eta_1 = 1 - \frac{T_m}{T_1}$

$\eta_2 = 1 - \frac{T_2}{T_m}$

$\frac{2}{2}$

Entropy Principles and its Applications – 2

14. For the flow of electric current through a resistor, $T_m = \sqrt{T_1 T_2}$

a) at steady state, internal energy of resistor is constant ✓

b) at steady state, temperature of resistor is constant ✓

c) W = Q ✓

d) all of the mentioned ✓

15. A car uses power of 25 hp for a one hour in a round trip. A thermal efficiency of 35 % can be assumed? Find the change in entropy if we assume ambient at 20 °C?

$1 hp = 0.7457$ kW

a) 554.1 kJ/K

b) 654.1 kJ/K ✓

c) 754.1 kJ/K

d) 854.1 kJ/K

$T_0 = 293.15$

$$E = \int W dt = 0.7457 \times 25 \times 3600_s = 67{,}113 \text{ KJ}$$

$$Q_{in} = E/\eta = \frac{67113}{0.35} \text{ KJ} = 191{,}751 \text{ KJ}$$

From 2nd Law, $\Delta S = Q/T_0 = \frac{191{,}751 \text{ KJ}}{293.15 \text{ K}} = 654.1 \frac{\text{KJ}}{\text{K}}$

16. A slab of concrete, 5 × 8 × 0.3 m, is used as a thermal storage mass in a house. The slab cools overnight from 23 °C to 18 °C in an 18 °C house, find the net entropy change associated with this process?

$\Delta S_{net} = -395.6 + 399 = +3.4$ KJ/K

Volume $= 5 \times 8 \times 0.3 = 12 m^3$. mass $= \rho \times$ Volume $= 2200 \times 12 = 26400$ Kg

$\rho_{concrete} = 2200 \frac{kg}{m^3}$

$T_1 = 23°C$

$T_2 = 18°C$

$T_2 = 291.15K$

$T_1 = 296.15K$

a) 0.4 kJ/K

b) 1.4 kJ/K

c) 2.4 kJ/K

d) 3.4 kJ/K ✓

V = constant and so $W_{12} = 0$.

$$\therefore Q_{12} = \Delta U = m C_v (T_2 - T_1) = 26400 \times 0.88 \times (-5) = -116160 \text{ KJ}$$

$$\Delta S_{system} = m(s_2 - s_1) = m C \ln(T_2/T_1) = 26400 \times 0.88 \ln\left(\frac{291.15}{296.15}\right) = -395.6 \text{ KJ/K}$$

$$\Delta S_{surr} = +116160/291.15 = +399 \text{ KJ/K}$$

17. Calculate the change in entropy if 1 kg of saturated liquid at 30 °C is converted into superheated steam at 1 bar and 200 °C.

For water as the system, $s_1 = s_{f@30°C} = 0.4369$ (Table A4)

$s_2 = s_{@ 1bar, 200°C} = 7.8342 \frac{KJ}{kgK}$ (Table A6)

a) 5.3973 kJ/K

b) 6.3973 kJ/K

c) 7.3973 kJ/K ✓

d) none of the mentioned

$$\Delta S = m(s_2 - s_1) = 1 Kg \times (7.8342 - 0.4369)$$

$$\Delta S = 7.3973 \text{ KJ/K}$$

1 bar = 100 KPa

+6

18. A thermal reservoir at 538 °C is brought into thermal communication with another thermal reservoir at 260 °C, and as a result 1055 kJ of heat is transferred only from the higher to lower temperature reservoir. Determine the change in entropy of the universe due to the exchange of heat between these two thermal reservoirs.

$$\Delta S_{System} = -1055/(538+273.15) + \frac{1055}{(260+273.15)}$$

$$= -1.300622 + 1.978805$$

$$= 0.678182 \text{ kJ/K}$$

$$\Delta S_{surroundings} = 0$$

$$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings} = 0.678182 \text{ kJ/K}$$

a) 0.378182 kJ/K
b) 0.478182 kJ/K
c) 0.578182 kJ/K
d) 0.678182 kJ/K ✓

+2

Entropy Transfer Mechanisms

19. Entropy can be transferred to or from a system in which of the following forms?
a) heat transfer ✓
b) mass flow ✓
c) both of the mentioned ✓
d) none of the mentioned ✗

20. The sign of entropy transfer is opposite to the sign of heat transfer.
a) true
b) false

Same sign.

21. The entropy of a system _____ by _____ when the mass of amount m enters it.
a) decreases, ms ✗
b) increases, ms ✓
c) decreases, s/m ✗
d) increases, s/m ✗

+3

VAPOUR POWER CYCLES

SIMPLE STEAM POWER CYCLE AND RANKINE CYCLE

22. A power cycle continuously converts ____ into ____
a) heat, heat X
b) work, heat X
c) heat, work ✓
d) work, work X

23. For a fluid undergoing cycle process,
a) there is no net change in its internal energy ✓
b) energy transfer as heat is equal to the energy transfer as work ✓
c) both of the mentioned ✓
d) none of the mentioned X

24. For a Rankine cycle, which of the following is true?
a) a reversible constant pressure heating process happens in steam boiler ✓
b) reversible adiabatic expansion of steam in turbine ✓
c) reversible constant pressure heat rejection in condenser ✓
d) all of the mentioned ✓

25. The work ratio is defined as the ratio of
a) positive work output to network output X
b) network output to the magnitude of the turbine work output ✓
c) heat input to the Network output X
d) none of the mentioned X

definition

ACTUAL VAPOUR CYCLE PROCESSES AND COMPARISON OF RANKINE AND CARNOT CYCLE

26. Which of the following losses occur in a cycle?
a) piping losses ✓
b) pump losses ✓
c) turbine losses ✓
d) all of the mentioned ✓

27. The only process which is different in Carnot and Rankine cycle is
a) compression in pump
b) expansion in turbine
c) heat rejection process
d) heat addition process

Rankine heat addition occurs while temperature changes b/w min & maximum.

Carnot heat addition occurs at constant temp.

All other processes are same.

6

MEAN TEMPERATURE OF HEAT ADDITION AND REHEAT CYCLE

28. In the Rankine cycle, heat is added reversibly at
a) constant pressure and constant temperature X
b) constant pressure and infinite temperature ✓
c) infinite pressure and constant temperature X
d) infinite pressure and infinite temperature X

29. Which of the following statement is true?
a) for given T_{mean}, lower is the T_2, higher will be the efficiency of Rankine cycle ✓
b) the lowest possible temperature of heat rejection is the surroundings temperature ✓
c) higher is the mean temperature of heat addition, higher will be the efficiency ✓
d) all of the mentioned ✓

30. To prevent erosion of blades, quality should not fall below
a) 85 % X
b) 90 %
c) 95 % X
d) 100 % X

Fact $x_{\text{turbe exit}} \geq 90\%$

31. Which of the following is true about a reheat cycle?
a) used to limit the quality at turbine exhaust at 0.90 when steam pressure is higher than $(p_1)_{max}$ ✓
b) after partial expansion in turbine, steam is brought back to boiler ✓
c) the steam is reheated by combustion gases ✓
d) all of the mentioned ✓

32. Why is steam not allowed to expand deep into two-phase region before being taken for reheating?
a) to protect the reheater tubes
b) to prevent solid deposits being left behind while evaporating
c) both of the mentioned
d) none of the mentioned

IDEAL REGENERATIVE CYCLE AND REGENERATIVE CYCLE

33. The mean temperature of heat addition can be increased by
a) increasing the amount of heat supplied at high temperatures ✓
b) decreasing the amount of heat added at low temperatures ✓
c) both of the mentioned ✓
d) none of the mentioned X

16

34. The efficiency of an ideal regenerative cycle is ____ the Carnot cycle efficiency.

B

a) greater than X
b) equal to X
c) less than X
d) none of the mentioned X

35. The ideal regenerative cycle is not practicable because
a) reversible heat transfer can't be obtained in finite time ✓
b) heat exchanger in turbine is mechanically impracticable ✓
c) there is high moisture content of steam in the turbine ✓
d) all of the mentioned ✓

36. The efficiency of regenerative cycle will be ____ the efficiency of the Rankine cycle.
a) greater than ✓
b) equal to X
c) less than X
d) none of the mentioned X

REHEAT-REGENERATIVE CYCLE AND FEEDWATER HEATERS

37. Why both reheating and regeneration is used together?
a) the effect of reheat alone on efficiency is very small ✓
b) regeneration has a marked effect on efficiency ✓
c) both of the mentioned ✓
d) none of the mentioned X

38. Which of the following statement is true?
a) open heater is also known as contact-type heater ✓
b) in an open type heater the extracted or bled steam is allowed to mix with the feed-water ✓
c) in a closed heater, the fluids are not allowed to mix together ✓
✓ d) all of the mentioned

39. Which of the following is true for an open feed-water heater?
a) it is simple, has low cost and low heat transfer capacity X
✓ b) a pump is required at each feed-water heater
c) both of the mentioned X
d) none of the mentioned X

40. The higher the number of heaters used, the ____ will be the cycle efficiency.
a) lower X
✓ b) higher ✓
c) efficiency does not depend on number of heaters X
d) none of the mentioned X

7

41. Which of the following statement is true?
a) in some cases, an increase in feed-water temperature may reduce the boiler efficiency ✓
b) number of heaters are optimized ✓
c) most often, five points of extraction are used ✓
d) all of the mentioned

GAS POWER CYCLES

CARNOT CYCLE, STIRLING CYCLE AND ERICSSON CYCLE

42. Gas turbines are used in aircraft propulsion because
a) they are light ✓
b) they are compact ✓
c) they have high power-to-weight ratio ✓
d) all of the mentioned ✓

43. The processes in compressor, turbine, diffuser and nozzle are
a) reversible
b) adiabatic
c) reversible and adiabatic
d) none of the mentioned

44. Which of the following statement is true?
a) mass flow rates of gases at engine inlet and exit are same ✗
b) the pressure at inlet and exit of engine are ambient pressures
c) both of the mentioned ✗
d) none of the mentioned ✗

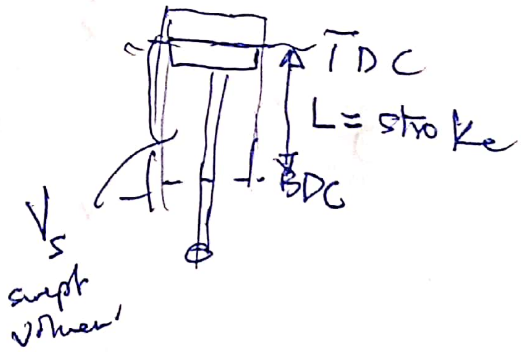
45. The propulsive efficiency is given by
a) work done by engine / propulsive power ✗
b) propulsive power / work done by engine ✗
c) energy input rate / propulsive power ✗
d) propulsive power / energy input rate

Definition?

AN OVERVIEW OF RECIPROCATING ENGINES

46. The distance between TDC and BDC is called ____
a) piston
b) bore
c) stroke
d) none of the mentioned

Fact



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47. The clearance volume is the ____ volume formed in cylinder when piston is at TDC.
a) minimum
b) maximum
c) average
d) none of the mentioned

Fact

48. A gasoline engine has a volumetric compression ratio of 10. Find the overall cycle efficiency.

$\gamma = 1.4.$

a) 0.602
b) 0.302
c) 0.502
d) 0.702

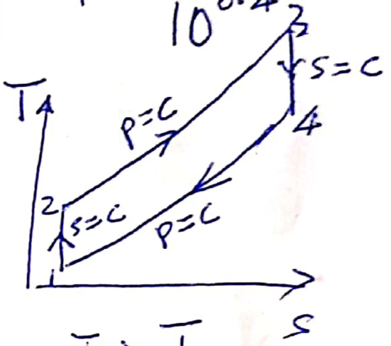
$r_v = 10$

$\eta_{th} = \left(1 - \frac{1}{r_v^{\gamma-1}}\right) = 1 - \frac{1}{10^{0.4}} = 0.602$

BRAYTON CYCLE – 1

49. The Brayton cycle consists of
a) two reversible isotherms and two reversible isobars
b) two reversible isochores and two reversible adiabatics
c) two reversible isotherms and two reversible isochores
d) two reversible isobars and two reversible adiabatics ✓

Fact



$T_4 > T_2$

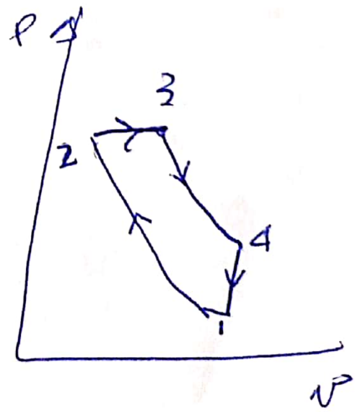
$T_2 > T_1$

50. The efficiency of Brayton cycle is given by (rk is the compression ratio)
a) $1/(r_k)^{\gamma-1}$
b) $1 - 1/(r_k)^{\gamma}$
c) $1 - 1/(rk)^{\gamma-1}$ ✓
d) $1/(rk)^{\gamma}$

Fact.

51. For the same compression ratio, the efficiency of Brayton cycle is ____ the efficiency of Otto cycle.
a) less than
b) equal to ✓
c) greater than
d) none of the mentioned

52. For Brayton cycle, average specific volume of air that compressor handles is ____ the same volume of gas in a gas turbine.
a) equal to
b) more than
c) less than
d) none of the mentioned



53. Which of the following is more popular for electricity generation?
a) gas turbine
b) steam power plant
c) both of the mentioned
d) none of the mentioned

54. Why is Otto cycle more suitable in reciprocating engine field?
a) reciprocating engine field cannot handle large volume of low-pressure gas
b) the engine size increases
c) the friction losses become more
d) all of the mentioned

BRAYTON CYCLE – 2

55. How can regeneration be used to improve the efficiency of Brayton cycle?
a) the energy of exhaust gas can be used to heat up the air which leaves the compressor
b) heat supplied from external source thus decreases
c) the amount of heat rejected also decreases
d) all of the mentioned

56. Which of the following statements is true for a regenerator?
a) mean temperature of heat addition decreases
b) mean temperature of heat rejection decreases
c) both of the mentioned
d) none of the mentioned

57. When the turbine efficiency and compressor efficiency decreases, the cycle efficiency ____
a) decreases
b) increases
c) remains same
d) none of the mentioned

58. As the pressure ratio increases, the efficiency steadily ____
a) decreases
b) increases
c) remains constant
d) none of the mentioned

59. The relation between maximum pressure ratio and optimum pressure ratio is given by — for a two stage
a) optimum pressure ratio = (maximum pressure ratio)/2
b) optimum pressure ratio = maximum pressure ratio
c) optimum pressure ratio = sqrt(maximum pressure ratio)
d) optimum pressure ratio = (maximum pressure ratio)^2

$r_{p\,opt} = (P_4/P_1)^{1/2}$

AIRCRAFT PROPULSION

60. Gas turbines are used in aircraft propulsion because
a) they are light ✓
b) they are compact ✓
c) they have high power-to-weight ratio ✓
d) all of the mentioned

Repeated question
Fact

61. Increasing the bypass ratio of turbofan engine ____ thrust.
a) does not affect
b) decreases
c) increases
d) none of the mentioned

Fact

+2

ADDITIONAL CALCULATION QUESTIONS

62 A heat pump is absorbing heat from the cold outdoors at 5 °C and supplying heat to a house at 25 °C at a rate of 18,000 kJ/h. If the power consumed by the heat pump is 1.9 kW, the coefficient of performance of the heat pump is

$|\dot{W}_{in}| = 1.9 kW$

$|\dot{Q}_H| = \frac{18{,}000 kJ}{3600 s} = 5.0 kW$

$COP_{hp} = \frac{|\dot{Q}_H|}{|\dot{W}_{in}|} = \frac{5}{1.9} = 2.63$

(a) 1.33 ✓
(b) 2.63 ✓
(c) 3.03
(d) 3.83
(e) 13.93

63 A heat engine cycle is executed with steam in the saturation dome. The pressure of steam is 1 MPa during heat addition and 0.4 MPa during heat rejection. The highest possible efficiency of this heat engine is

T_{sat} @ 1000 kPa

$P_H = 1000 kPa$, $T_H = 179.88°C (452.88K)$ See table A5

$P_L = 400 kPa$, $T_{sat@400kPa} = T_L = 143.61°C (416.61K)$ · Table A5

$\eta_{max} = \eta_{carnot} = \left(1 - \frac{T_L}{T_H}\right) \times 100\% = \left(1 - \frac{416.61}{452.88}\right) \times 100\%$

$\eta_{max} = 8.008\% \simeq 8.01\%$

(a) 8.01 % ✓
(b) 15.61 %
(c) 20.21 %
(d) 79.81 %
(e) 100 %

+4

64 Combustion gases with a specific heat ratio of 1.3 enter an adiabatic nozzle steadily at 800 °C and 800 kPa with a low velocity, and exit at a pressure of 85 kPa. The lowest possible temperature of combustion gases at the nozzle exit is

(a) 42.9 °C

(b) 236.7 °C

(c) 366.6 °C ✓

(d) 476.7 °C

(e) 639.8 °C

$P_{inlet} = 800\,kPa$

$T_{inlet} = 800^\circ C = 1073\,K$

$P_{exit} = 85\,kPa$

$\gamma = 1.3$

$$T_{exit} = T_{inlet}\left(\frac{P_{exit}}{P_{inlet}}\right)^{\gamma-1/\gamma} - 273\ ^\circ C$$

$$= 1073\left(\frac{85}{800}\right)^{0.3/1.3} - 273 = 639.6 - 273 = 366.6^\circ C$$

65 Steam enters an adiabatic turbine steadily at 400 °C and 5 MPa, and leaves at 20 kPa. The highest possible percentage of mass of steam that condenses at the turbine exit and leaves the turbine as a liquid is

(a) 4.1 %

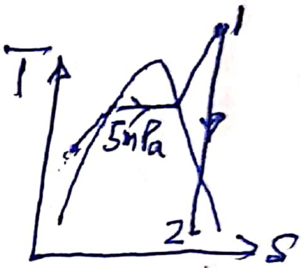
(b) 8.1 %

(c) 11.8 %

(d) 17.8 % ✓

(e) 0.1 %

$s_2 = s_f + x_2 s_{fg}$. $\quad x_2 = \frac{6.6483 - 0.8320}{7.0752}$ Adiabatic Turbine $s_1 = s_2$.



$P_1 = 5000\,kPa$, $T_1 = 400^\circ C$ } From table A6. $s_1 = 6.6483\ \frac{kJ}{kg}K$

$P_2 = 200\,kPa$ $\quad s_{f@200kPa} = 0.8320\ \frac{kJ}{kg}K$ $\quad (1 - x_2)\times 100\%$

$x_2 = 0.822$ $\quad s_{fg@200kPa} = 7.0752\ \frac{kJ}{kg}K$ $\quad \boxed{= 17.8\%}$

66 Liquid water enters an adiabatic piping system at 15 °C at a rate of 8 kg/s. If the water temperature rises by 0.2 °C during flow due to friction, the rate of entropy generation in the pipe is:

(a) 23.2 W/K ✓

(b) 55.2 W/K

(c) 68.2 W/K

(d) 220.2 W/K

(e) 443.2 W/K

$T_{in} = 288\,K$

$T_{out} = 288.2\,K$

$$\dot{S}_{gen} = \dot{m}\, C_{p_w} \ln\left(\frac{T_{out}}{T_{in}}\right) = 8\,\frac{kg}{s} \times 4.18\,\frac{kJ}{kg\,K} \ln\left(\frac{288.2}{288}\right)$$

$$= 0.0232\ \frac{kW}{K} = 23.2\ W/K$$

∴ Adiabatic piping

+6

$1 kPa = 1 kN/m^2$ $\quad 1 kN m = 1 kJ$

67 Liquid water is to be compressed by a pump whose isentropic efficiency is 75 percent from 0.2 MPa to 5 MPa at a rate of 0.15 m³/min. The required power input to this pump is

$P_f = 5000 kPa$
$P_{in} = 200 kPa$
$\dot{V} = \frac{15 m^3}{60 s}$
$\eta_p = 0.75$

(a) 4.8 kW

(b) 6.4 kW

(c) 9.0 kW

(d) 16.0 kW

(e) 12 kW

$$|\dot{W}_{rev}| = \dot{V}(P_f - P_{in}) = \frac{0.15 m^3}{60 s} \times (5000-200) \frac{kN}{m^2}$$

$$= 12 \frac{kJ}{s} = 12 kW$$

$$|\dot{W}_{act}| = |\dot{W}_{rev}| / \eta_p = 12/0.75 = 16 kW$$

68 Steam enters an adiabatic turbine at 8 MPa and 500 °C at a rate of 18 kg/s, and exits at 0.2 MPa and 300 °C. The rate of entropy generation in the turbine is

(a) 0 kW/K

(b) 7.2 kW/K

(c) 21 kW/K

(d) 15 kW/K

(e) 17 kW/K

$P_1 = 8000 kPa$, $T_1 = 500°C$ | From table A6 $s_1 = 6.7266 \frac{kJ}{kg K}$

Exit $P_2 = 200 kPa = 0.2 MPa$, $T_2 = 300°C$ | Table A6, $s_2 = 7.8941 \frac{kJ}{kg K}$

$$\dot{S}_{gen} = \dot{m}(s_2 - s_1) = 0.18 \frac{kg}{s} \times (7.8941 - 6.7266) \frac{kJ}{kg K}$$

$\dot{S}_{gen} = 21.015 kW/K$

$\simeq 21 kW/K$

69 In an ideal Brayton cycle, air is compressed from 95 kPa and 25 °C to 1100 kPa. Under cold-air-standard conditions, the thermal efficiency of this cycle is

For the compressor
$P_{out} = 1100 kPa$
$P_{in} = 95 kPa$
$r_p = \frac{P_{out}}{P_{in}}$
$\gamma = 1.4$

(a) 45.3 percent

(b) 50.3 percent

(c) 62.3 percent

(d) 73.3 percent

(e) 86.3 percent

$r_p = 1100/95 = 11.579$

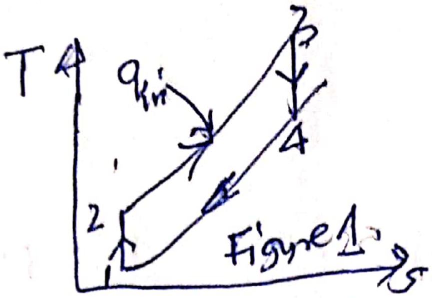
$$\eta_{Brayton} = \left[1 - \frac{1}{r_p^{(\gamma-1/\gamma)}}\right] \times 100\%$$

$$= \left(1 - \frac{1}{11.759^{0.4/1.4}}\right) \times 100\% = 50.3\%$$

76

$T_1 = 20^\circ C = 293K$

$T_3 = 1000^\circ C = 1273K$



70 Consider an ideal Brayton cycle executed between the pressure limits of 1200 and 100 kPa and temperature limits of 20 and 1000 °C with argon as the working fluid. The network output of the cycle is approximately:

For Argon $C_p = 0.5203\ kJ/kg\,K$ Lecture notes

(a) 68 kJ/kg

(b) 93 kJ/kg

(c) 157.7 kJ/kg

(d) 186 kJ/kg

(e) 310 kJ/kg

$\gamma = 1.667$

$T_2 = T_1 (r_p)^{\gamma-1/\gamma} = 293\left(\frac{1200}{100}\right)^{0.667/1.667} = 791.9K$

$q_{in} = C_p(T_3 - T_2)$

$= 0.5203(1273 - 791.9)$

$= 250.316\ kJ/kg$

$\eta_{th} = \left[1 - \frac{1}{12^{0.667/1.667}}\right] = 0.63$

$|W_{net}| = \eta_{th} q_{in} = 0.63 \times 250.316 = 157.7\ kJ/kg$

71 An ideal Brayton cycle has a network output of 150 kJ/kg and a back-work ratio of 0.4. If both the turbine and the compressor had an isentropic efficiency of 85 percent, the network output of the cycle would be approximately:

For the ideal Brayton Cycle

$bwr = \frac{|W_c|}{|W_t|}$ back work ratio

(a) 74.1 kJ/kg

(b) 94.9 kJ/kg

(c) 109.1 kJ/kg

(d) 128.1 kJ/kg

(e) 177.1 kJ/kg

$(W_{net})_{ideal}\ |W_t| - |W_c| = 150\ kJ/kg$. But $\frac{|W_c|}{|W_t|} = 0.4$

$|W_{net}|_{ideal} = |W_t| - 0.4|W_t| = 150$ $\quad |W_c| = 0.4|W_t|$

$0.6|W_t| = 150 \Rightarrow |W_t| = 250\ kJ/kg$ $\quad |W_c| = 100\ kJ/kg$

$|W_{net}|_{actual} = \eta_t |W_t| - |W_c|/\eta_c = 0.85(250) - \frac{100}{0.85} = 94.85\ kJ/kg \simeq 94.9\ kJ/kg$

72 In an ideal Brayton cycle, air is compressed from 100 kPa and 25 °C to 1 MPa, and then heated to 927 °C before entering the turbine. Under cold-air-standard conditions, the air temperature at the turbine exit is approximately:

$T_{in,turbine} = 927 + 273 = 1200K = T_3$ See Figure 1 above.

(a) 348.5 °C

(b) 426.1 °C

(c) 622.1 °C

(d) 733.1 °C

(e) 825.2 °C

$\gamma = 1.4$

$T_{exit,turbine} = T_4 = T_3 \left(\frac{P_{exit}}{P_{in}}\right)^{\gamma-1/\gamma} = 1200K\left(\frac{100}{1000}\right)^{0.4/1.4}$

$= 621.5K\ (348.5^\circ C)$

$P_{exit,turbine} = P_{in,compressor} = 100kPa.$

$P_{in,turbine} = P_3 = P_2 = 1000kPa$

+6.

73 In an ideal Brayton cycle with regeneration, argon gas is compressed from 100 kPa and 25 °C to 400 kPa, and then heated to 1200 °C before entering the turbine. The highest temperature that argon can be heated in the regenerator is approximately:

$\gamma = 1.667$

$c_p = 0.5203 \; kJ/kg\,K$

$r_p = 400/100 = 4$

$T_{1,\,compressor} = 298 K$

$T_{3,\,inlet\,turbine} = 1473 K$

$T_{4,\,turbine\,outlet} = T_3 \left(\frac{1}{r_p}\right)^{\gamma-1/\gamma} = \frac{T_3}{r_p^{\gamma-1/\gamma}} = \frac{1473}{4^{0.667/1.667}}$

$T_4 = 845.9 K \; (572.9 °C)$

(a) 245.6 °C

(b) 845.6 °C

(c) 689.1 °C

(d) 368.1 °C

(e) 572.9 °C ✓

74 Pressurized feed-water in a steam power plant is to be heated in an ideal open feed-water heater that operates at a pressure of 2 MPa with steam extracted from the turbine. If the enthalpy of feed-water is 252 kJ/kg and the enthalpy of extracted steam is 2810 kJ/kg, the mass fraction of steam extracted from the turbine is approximately:

$h_2 = 252 \; kJ/kg$

$h_3 = h_{f@2000kPa} = 908.47 \; kJ/kg$ Table A5

Mixing in the OFWH

$h_6 = 2810 \; kJ/kg$ $\quad h_3 = y h_6 + (1-y) h_2 \Rightarrow 908.47 = y(2810-252) + 252$

$\therefore y = \frac{908.47-252}{(2810-252)} = 0.2566 = 25.7\%$

(a) 10.1 percent

(b) 14.2 percent

(c) 25.7 percent ✓

(d) 36.1 percent

(e) 49.9 percent

75 Consider a steam power plant that operates on the regenerative Rankine cycle with one open feed-water heater. The enthalpy of the steam is 3374 kJ/kg at the turbine inlet, 2797 kJ/kg at the location of bleeding, and 2346 kJ/kg at the turbine exit. The net power output of the plant is 120 MW, and the fraction of steam bled off the turbine for regeneration is 0.172. If the pump work is negligible, the mass flow rate of steam at the turbine inlet is approximately:

$h_5 = h_{in} = 3374 \; kJ/kg$

$h_6 = h_{ex} = 2797 \; kJ/kg$

$h_7 = h_{exit} = 2346 \; kJ/kg$

$|\dot{W}_{net}| = 120{,}000 \; kW$

$|W_{net}| = (3374-2797) + (1-0.172)(2797-2346) = 950.428 \; kJ/kg$

(a) 117 kg/s

(b) 126 kg/s ✓

(c) 219 kg/s

(d) 268 kg/s

(e) 679 kg/s

See Fig 2 above.

$\dot{m} = \frac{|\dot{W}_{net}|}{|W_{net}|} = \frac{120{,}000 \; kJ/s}{950.428 \; kJ/kg}$

$\dot{m} = 126.2 \; kg/s \simeq 126 \; kg/s$

$|W_{net}| = \eta_{carnot} \times q_{in} = 0.371 \times 1794.9 = 665.9\,kJ/kg$

76 Consider a steady-flow Carnot cycle with water as the working fluid executed under the saturation dome between the pressure limits of 3 MPa and 10 kPa. Water changes from saturated liquid to saturated vapour during the heat addition process. The network output of this cycle is approximately:

(a) 665.9 kJ/kg

(b) 887.8 kJ/kg

(c) 1039.8 kJ/kg

(d) 1129.8 kJ/kg

(e) 1439.8 kJ/kg

$P_H = 3000\,kPa,\ T_H = 233.85 + 273 = 506.85\,K$

$P_L = 10\,kPa,\ T_L = 45.81 + 273 = 318.81\,K$

$\eta_{carnot} = 1 - \frac{318.81}{506.85} = 0.371$

At P_H, $q_{in} = h_{fg@3000kPa} = 1794.9\,kJ/kg$.

77 A simple ideal Rankine cycle operates between the pressure limits of 10 kPa and 3 MPa, with a turbine inlet temperature of 600 °C. Disregarding the pump work, the cycle efficiency is approximately:

read from A6

(a) 24.3 percent

(b) 37.3 percent ✓

(c) 52.3 percent

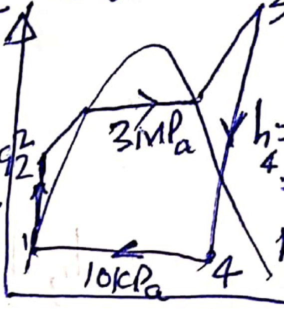
(d) 63.3 percent

(e) 71.3 percent

$s_3 = s_4 = 7.5103$

$h_3 = 3682.8\,kJ/kg$

$|q_{out}| = 2380.6 - 191.81 = 2188.79$



$x_4 = 0.915$

$h_4 = 191.81 + 0.915(2392.1) = 2380.6\,kJ/kg$

Assume $h_1 \approx h_2 = 191.81$

$x_4 = \frac{s_4 - s_{f@10kPa}}{s_{fg@10kPa}} = \frac{7.5103 - 0.6492}{7.4996}$

$q_{in} = 3682.8 - 191.81 = 3490.99\,kJ/kg$

$\eta = \left[1 - \frac{2188.79}{3490.99}\right] \times 100\%$

$\eta = 37.3\%$

78 A simple ideal Rankine cycle operates between the pressure limits of 10 kPa and 5 MPa, with a turbine inlet temperature of 600 °C. The mass fraction of steam that condenses at the turbine exit is approximately:

$s_3 = \cancel{6.9781} = s_4 = 7.2605\,kJ/kg$ Table A6

5000, 600°C,

(a) 5.9 percent

(b) 8.9 percent

(c) 11.8 percent ✓

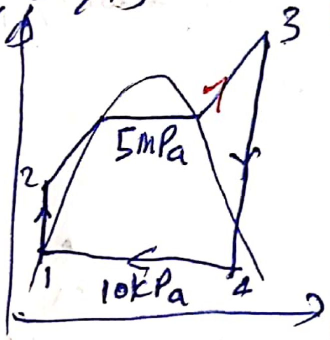
(d) 14.8 percent

(e) 17.7 percent

$s_4 = s_{f@10kPa} + x_4 s_{fg@10kPa}$

$x_4 = \frac{7.2605 - 0.6492}{7.4996}$

$= 0.8816$



$(1 - x_4) \times 100\% = 11.84\%$

$\simeq 11.8\%$

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