Explanation Chapter 7

7.1 Which of these options will not increase the efficiency of a Rankine Cycle?
a) Superheating the vapor to higher temperatures
b) Increasing the pump input pressure
c) Increasing the boiler pressure
d) Decreasing the condenser pressure
Ans: B. When the area inside the Ts-diagram increases, the efficiency also increases. If the pressure of the pump is increased, the lower pressure of the liquid into the pump is increased, resulting in a smaller area, thus decreasing the efficiency of the Rankine Cycle.

7.2 Is it possible to have a pressure of 5 kPa in a condenser that is placed near a river and cooled by the water of the river that has a temperature of 10°C? And in a condenser that is placed in the desert and cooled with outside air of 35°C?
a) Only for the one near the river
b) Only for the one near the desert
c) Yes, it is possible for both
d) No, for both it is not possible
Ans: C. Only for the one near the river, because the saturation temperature of steam at 5 kPa is 35.87°C, which is much higher than the temperature of the cooling water, but lower than the temperature of the air in the desert.

7.3 How is the power output affected by a non-adiabatic turbine in a simple Rankine cycle?
a) The power output will increase
b) The power output will decrease
c) The power output will stay the same
d) The power output will increase only if the state of the working fluid at the turbine exit is a saturated vapour
e) The power output is not affected by the heat transfer
Ans: B. Q_{out} increases, therefore the efficiency of the cycle will decrease. $\eta = \frac{W_{\text{net}}}{Q_{\text{in}}} = 1 - \frac{Q_{\text{out}}}{Q_{\text{in}}}$

7.4 What is/are the correct formula(s) that describe the thermal efficiency of a simple Rankine cycle? Hint: Multiple answers are possible, start with the pump
a) $\eta = \frac{W_{net}}{Q_{in}}$
b) $\eta = 1 - \frac{Q_{out}}{Q_{in}}$
c) $\eta = \frac{Q_{out} - Q_{in}}{Q_{in}}$
d) $\eta = \frac{Q_{in} - Q_{out}}{Q_{in}}$
e) $\eta = 1 - \frac{h_4 - h_1}{h_3 - h_2}$
f) $\eta = 1 - \frac{W_{net}}{Q_{in}}$
Ans: A, B, D, E. All 4 formula’s describe the thermal efficiency of a simple Rankine cycle, however they are rewritten to different properties.

7.5 What is the order of the elements in a simple Rankine cycle starting with A?
a) Pump, boiler, condenser, turbine
b) Boiler, pump, turbine, condenser
c) Condenser, turbine, pump, boiler
d) Pump, boiler, turbine, condenser
Ans: D. For a Rankine cycle, always start at the pump, making a clockwise encirclement.

7.6 Complete the sentence: A Rankine cycle operating on a low pressure limit of P_1 and a high pressure limit of P_2 … Hint: Draw a P-V curve to gain a better understanding of this question.
a) has a higher thermal efficiency than the Carnot cycle operating between the same pressure limits
b) has a lower thermal efficiency than a Carnot cycle operating between the same pressure limits
c) has the same thermal efficiency as a Carnot cycle operating between the same pressure limits
d) may be more or less efficient depending on the magnitudes of P_1 and P_2
Ans: A. Area under P-V curve for a Rankine cycle will be more as compared to a Carnot cycle

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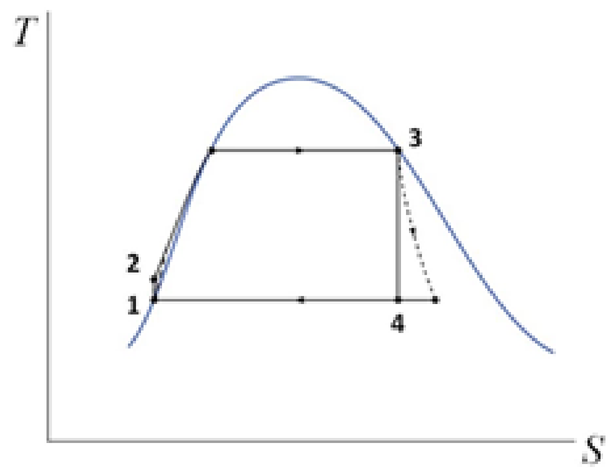
7.7 A Rankine cycle comprises of:
a) 2 isentropic processes and 2 constant pressure processes
b) 2 isothermal processes and 2 constant pressure processes
c) 2 isentropic processes and 2 constant volume processes
d) None of the above
Ans: A. A Rankine cycle is a reversible cycle which has two constant pressures and two constant temperature processes.

7.8) The Rankine cycle efficiency of a good simple steam power plant may be in the range of:
a) 90%-95%
b) 25% - 35%
c) 70% - 80%
d) 15% - 20%
Ans: B. Efficiency of a Rankine cycle in actual working conditions is found to be between 25% - 35%.

7.9 Sometimes the pump work in vapor power cycle is neglected because:
a) The pump work is not considered in the efficiency of the vapour power cycle
b) The pump work is very small compared to the heat addition
c) The pump work is very small compared to the turbine work
d) None of the above
Ans: C. Compared to the work output of a turbine, the work needed to drive the pump is negligible. To get an exact efficiency however, the work input for the pump should be taken into account.

7.10 Water enters an ideal pump as a saturated liquid with a pressure of 50 kPa. It leaves with a pressure of 20 MPa. The water has a mass flow rate of 10 kg/s. How much work does this pump require?
a) 20.5 kW
b) 19.5 kW
c) 205 kW
d) 195 kW
Ans: C. Use the formula $v * (P_2 - P_1) * m$ = 0.00103 * (20000 - 50) * 10 = 205 kW

7.11 What is happening to the vapour quality in a simple Rankine cycle when the isentropic efficiency of the turbine is not 100% and the output pressure remains the same?
a) x will increase
b) x will decrease
c) x will stay the same
d) The output of turbine is vapour, so x does not exist
e) The output of the turbine is saturated vapor, so x is 1
Ans: A. Looking at the figure (T-s diagram), it can be seen that a shift to the right will appear. That means that the quality of the vapour will increase, and this will result in an increase to x.



7.12 Will the net work change if we decrease the isentropic efficiency of a turbine in a Rankine cycle?
a) No, the net work is not related to the turbine
b) No, because the work input will decrease too. Therefore the efficiency remains the same.
c) Yes, it will increase because vapour quality increases too
d) Yes it will decrease because the enthalpy of the steam at the exit of the turbine will be larger
e) Yes, it will decrease because the amount of heat rejected will decrease
Ans: D. The exit enthalpy of the turbine will increase together with the decrease in isentropic efficiency. Therefore, the $w_{out} = h_{in} - h_{out}$ of the turbine will decrease too. As w_{in} is not changed and the work net is the difference between w_{out} and w_{in}, the total net work will decrease.

7.13 Steam enters a turbine at T = 400 °C and P = 3 MPa. It leaves with a pressure of 50 kPa and the turbine has an isentropic efficiency of 0.8. How much specific work does this turbine generate?
a) 572 kJ/kg
b) 659 kJ/kg
c) 830 kJ/kg
d) 1038 kJ/kg
Ans: B. The first step is to determine the two known independent thermodynamic properties in each state. To be able to make use of the isotropic efficiency and extra point is added, point 2 as if it was the turbine was ideal. This is tabulated to make it easier to order.

property	P (kPa)	T (°C)	h (kJ/kg)	S (kJ/kgK)	x	η_{iso}
State 1	**3000**	**400**	3232	6.9235		
State 2	**50**					**0.8**
State 2s	**50**			**s_1**		

The bold values are the initially known properties. Corresponding values for state 1 can be looked up in table A6. The quality of state 2s can now be determined using the s_f and s_g found in table A5 at the corresponding pressure.

$$x_{2s} = \frac{s - s_f}{s_g - s_f} = \frac{6.9235 - 1.0912}{7.5931 - 1.0912} = 0.897$$

Now h_{2s} can be determined using:

$$h_{2s} = x * h_{fg} + h_f = 0.897 * 2304 + 341 = 2408 \frac{kJ}{kg}$$

Using the formula for isotropic efficiency h_2 can be calculated

$$h_2 = h_1 - \eta_{iso} * (h_1 - h_{2s}) = 3232 - 0.8 * (3232 - 2408) = 2573 \frac{kJ}{kg}$$

To calculate the specific work output:

$$w_{out} = h_1 - h_2 = 3232 - 2573 = 659\, kJ/kg$$

7.14 Steam enters a turbine at T = 500 °C and P = 4 MPa. It leaves as a saturated vapor with a pressure of 40 kPa. What is the isotropic efficiency?
a) 0.80
b) 0.85
c) 0.90
d) 0.95
Ans: A. First we create the extra point 2s and enter all known values into the table. The bold values are known from the start.

property	P (kPa)	T (°C)	h (kJ/kg)	S (kJ/kgK)	x	η_{iso}
State 1	**4000**	**500**	3446	7.0922		
State 2	**40**		2636		**1**	
State 2s	**40**		2435	**s_1**		

Once again, start by looking up the state of 2s. It is a mixture so calculate the quality and use that to find the corresponding enthalpy.

@ 40 kPa, s_f = 1.0261 kJ/kgK and s_g = 7.6691 kJ/kgK

$$x_{2s} = \frac{s_{2s} - s_f}{s_g - s_f} = \frac{7.0922 - 1.0261}{7.6191 - 1.0261} = 0.913$$

$$h_{2s} = h_f + h_{gf} * x = 318 + 2318 * 0.913 = 2435\, kJ/kg$$

Now that these values are known the isotropic efficiency can be calculated:

$$\eta_{iso} = \frac{h_1 - h_2}{h_1 - h_{2s}} = \frac{3446 - 2636}{3446 - 2435} = 0.8$$

7.15 A pump increases the pressure of a saturated liquid at 50 kPa to a pressure of 4 MPa. It has an isentropic efficiency of 0.8. How much work does this pump require?
a) 0 kJ/kg
b) 3 kJ/kg
c) 4 kJ/kg
d) 5 kJ/kg
Ans: D. The ideal increase in enthalpy can be calculated using $\Delta h = \Delta P * v$. Next simply divide by the isotropic efficiency to find actual h increase.

$$\Delta h_{2s} = v * \Delta P = 0.001030 * 3950 = 4\,\mathrm{kJ/kg}$$

$$\Delta h_2 = \frac{\Delta h_{2s}}{\eta_{iso}} = \frac{4}{0.8} = 5\,\mathrm{kJ/kg}$$

7.16 A condenser has a mass flow of 5 kg/s. It cools an saturated vapor at a pressure of 20 kPa. What is the rate of heat extraction from the condenser?
a) 1998.4 kW
b) 2357.7 kW
c) 9992 kW
d) 11788 kW
Ans: D. @P = 20 kPa -> h_{fg} = 2357.7 kJ/kg

$$Q_{out} = h_{fg} * m = 2357.7 * 5 = 11788\, kJ/kg$$

7.17 In a boiler, coal with a heating value of 30 MJ/kg is burned. The boiler efficiency is 75%. It heats a saturated liquid at 8 MPa to 500°C. The mass flow is 1 kg/s. How much coal is burnt per second?
a) 0.09 kg/s
b) 0.12 kg/s
c) 0.15 kg/s
d) 0.20 kg/s
Ans: A.
P_1 = 8 MPa, x_1 = 0, h_1 = 1317.1 kJ/kg
P_2 = 8 MPa, T_2 = 500°C, h_2 = 3400 kJ/kg

$$\Delta h = 3400 - 1317.1 = 2082.9\, kJ/kg$$

$$\frac{2082.9 * 1}{30000 * 0.75} = 0.0926\, kg/s$$

7.18 Water enters a pump in state 1, as a saturated liquid with a certain pressure, P_1. The water leaves as a compressed liquid with P_2. The pump has an isotropic efficiency of $\eta_{isopump}$. What is the formula that you can use to calculate the enthalpy value for point 2?

$$h_2 = h_1 + v * (P_2 - P_1)/\eta_{isopump}$$