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**ROSE-HULMAN Institute of Technology**
*Department of Mechanical Engineering*

ME301 – Thermodynamics II Fall 2012-2013

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**Name**

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# Exam 1

Sep 20, 2012

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| Problem 1 | ______/ 34 |
| Problem 2 | ______/ 34 |
| Problem 3 | ______/ 32 |
| Total | ______/ 100 |

Show all work for full credit.

Open book, computer use for computational purposes, one 8 ½ x 11" handwritten equation sheet.

If you use tabular data from your text, do **not** interpolate values. Use the nearest value in the table(s).

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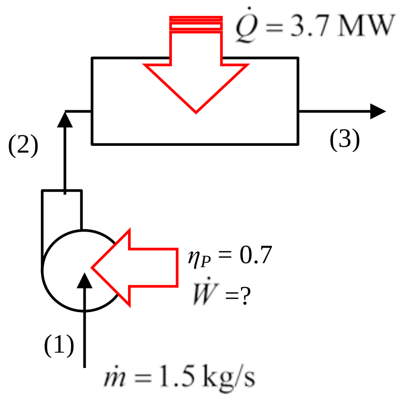
## Problem 1 (34 pts)

A pump with isentropic (adiabatic) efficiency of $\eta_P = 0.7$ compresses $\dot{m} = 1.5$ kg/s of saturated liquid water from $P_1 = 200$ kPa to $P_2 = 2.5$ MPa. The water is then passed through a constant pressure steam generator which receives heat transfer in the amount of $\dot{Q} = 3.7$ MW. The temperature and pressure of the surroundings are $T_0 = 300$ K and $P_0 = 100$ kPa. The properties at state (1) are given below.

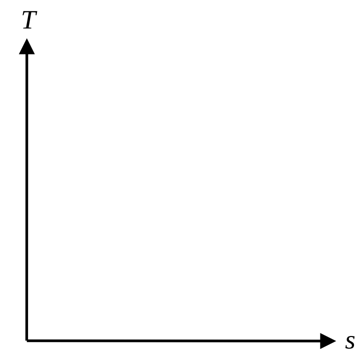



(1) $P_1 = 200$ kPa

Saturated liquid
$T_1 = 120.2$°C
$v_1 = 0.0011$ m$^3$/kg
$u_1 = 504.5$ kJ/kg
$h_1 = 504.7$ kJ/kg
$s_1 = 1.530$ kJ/kg-K

(2) $P_2 = 2.5$ MPa

(3) $P_3 = P_2$




(a) Sketch the two step process on the $T$-$s$ diagram above.
(b) Find the required power into the pump, $\dot{W}_{in}$, in kW.
(c) Find the specific enthalpy of the steam leaving the steam generator, $h_3$, in kJ/kg and state the phase (liquid, superheated vapor, saturated mixture, etc.) of the steam leaving the steam generator.
(d) Find the exergetic efficiency (second law efficiency) of the pump, $\varepsilon_P$.

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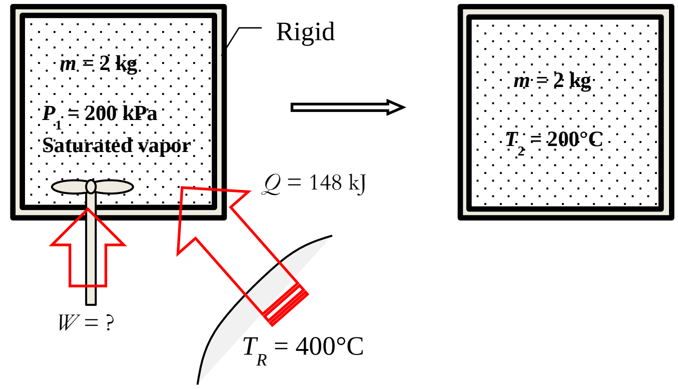
## Problem 2 (34 pts)

A **rigid** vessel contains 2 kg of steam. Initially the steam is a **saturated vapor** at $P_1$ = 200 kPa. Heat transfer from a reservoir at $T_R$ = 400°C is then added to the steam in the amount of $Q$=148 kJ, along with an unknown amount of paddle wheel work, $W$, until the steam is at $T_2$=200°C. The temperature and pressure of the surroundings are $T_0$ = 300 K and $P_0$ = 100 kPa, respectively.




Find

(a) the work the paddle wheel does on the steam (in kJ) and
(b) the change in exergy (in kJ) of the steam.
(c) Using the results of (a) and (b), find the amount of exergy destroyed (in kJ) in the process.

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## Problem 3 (32 pts)

(a) A turbine with an adiabatic efficiency (isentropic efficiency) of $\eta_T < 1$ operates between pressures of 10 MPa and 50 kPa. The inlet is a saturated vapor.

i. (3 pts) How does the actual exit pressure compare to the isentropic exit pressure?
- o $P_2 < P_{2s}$
- o $P_2 = P_{2s}$
- o $P_2 > P_{2s}$
- o Insufficient info to determine

ii. (3 pts) How does the actual exit specific entropy compare to the isentropic exit specific entropy?
- o $s_2 < s_{2s}$
- o $s_2 = s_{2s}$
- o $s_2 > s_{2s}$
- o Insufficient info to determine

iii. (3 pts) How does the actual exit temperature compare to the isentropic exit temperature?
- o $T_2 < T_{2s}$
- o $T_2 = T_{2s}$
- o $T_2 > T_{2s}$
- o Insufficient info to determine

(b) (3 pts) The work out of a closed system is $W_{12} = 100$ kJ. The system's volume increases from $\forall_1 = 1$ m$^3$ to $\forall_2 = 2$ m$^3$ during the work addition. If the environment is at $T_0 = 300$ K and $P_0 = 100$ kPa, how much exergy has left the system because of work?

- o $A_{W,\text{out}} = 0$ kJ
- o $A_{W,\text{out}} = 100$ kJ
- o $A_{W,\text{out}} = 200$ kJ
- o Insufficient info to determine

(c) An electrical resistance heater operates at steady-state with an input electrical power of $\dot{W}_{in} = 5$ kW. The heater converts all of the electrical power into heat transfer, which is dissipated to the heated space. The temperature of the heating element is $T_{elem} = 700$ K and the heated space is at $T_{space} = 300$ K and $P_{space} = 100$ kPa.

i. (2 pts) What is the **energy-based efficiency** of the heater?
- o $\eta_{\text{heat}} = 0\%$
- o $\eta_{\text{heat}} = 43\%$
- o $\eta_{\text{heat}} = 57\%$
- o $\eta_{\text{heat}} = 100\%$
- o Insufficient info to determine

ii. (4 pts) What is the **exergetic efficiency** of the heater?
- o $\varepsilon_{\text{heat}} = 0\%$
- o $\varepsilon_{\text{heat}} = 43\%$
- o $\varepsilon_{\text{heat}} = 57\%$
- o $\varepsilon_{\text{heat}} = 100\%$
- o Insufficient info to determine

(d) Circle the correct response.

i. (3 pts) **True / False** For a turbine operating at steady-state, the total power produced and the useful power are the same.

ii. (3 pts) **True / False** A change in exergy can be negative.

iii. (3 pts) **True / False** Exergy destruction can be negative.

(e) (5 pts) Hot combustion gases at $T_R$ = 700°C provide 5 MW of heat transfer to steam at $T_{boiler}$ = 600°C in a Rankine cycle. If the boiler temperature were raised to $T_{boiler}$ = 650°C instead, would you expect the cycle efficient to go up, down, or remain the same? Explain your answer.