

**PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING
MCEG 2013- THERMODYNAMICS I
FALL 2021**

- I. COURSE DESCRIPTION IN ABET FORMAT**
- II ASSESSMENT RESULTS FOR CURRENT AND PAST THREE PERIODS**
Program Outcomes Assessed in Course
Assessment Summary of Class Semester Averages for Outcomes
End of Semester Course Outcomes Assessment Reports
- II. TESTS**
Summary of Topics covered by Test
Original Test Questions & Master Solution/grading scheme used
(Summary of topics can be a separate page or include on the assignment itself)
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)
- III. QUIZZES**
Summary of Topics covered by Quiz
Original Quiz Questions & Master Solution/grading scheme used
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)
- IV. HOMEWORK ASSIGNMENTS**
Summary of Topics covered by Homework
Original Homework Questions & Master Solution/grading scheme used
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)

[Include any other evaluation used and omit any method above method (Test, Quizzes, Homework, Laboratory and Project reports) that was not used]

(Note: All Pages shown in Yellow should be printed on YELLOW PAPER)

Course Description in ABET Format

1.	Course number and name:	MCEG 2301 [2013] Thermodynamics I
2.	Credits and contact hours:	3 credit hours; 3 contact hours
3.	Instructor's or course coordinator's name:	Dr. Paul O. Biney
4.	Text book: Title:	Thermodynamics: An Engineering Approach, 9 th edition, 2018, McGraw Hill: ISBN 978-1-259-82267-2.
	Author:	Yunus Cengel, Michael A. Boles & Mehmet Kanoglu,
	Publisher, Year & Edition:	McGraw Hill, 2018
	a. Other Supplemental material	Fundamentals of Engineering Thermodynamics, 7th edition M. J. Moran, H. N. Shapiro, D. D. Boettner and M.B. Bailey ISBN-10: 0470495901 ISBN-13: 978- 0470495902
5.	Specific course information	
	a. Brief description of the content of the course (catalog description)	First Law, transformation of energy, theoretical limitations, Second Law, absolute temperature, entropy, and available energy, properties of gases, liquids, and vapors, and irreversibility.
	b. Prerequisites or	MATH 2414 [2024]* and PHYS 2325 [2513].
	Co-requisites	None
	c.**Indicate whether a required, elective, or selected elective (as per definition provided) course in the program	Required
6.	a. Specific goals for the course specific outcomes of instruction (e.g. The student will be able to explain the significance of current research about a particular topic.)	b. Explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.
	Given a complex engineering problem, students will be able to :	The specific goals for the course specific outcomes listed on the left column will address the following student learning outcomes:
	1. Identify and Formulate engineering/technical/computing problems using principles of engineering/mathematics/science Given an engineering problem, the students are able to: i. Understand the given problem and identify the subject area and concepts involved. ii. Convert the problem into a well labeled sketch (such as free body diagram, flow chart, functional block diagram, schematic diagram). iii. Formulate the engineering problem into a mathematical model [using basic, intermediate and advanced mathematics ranging from algebra & trigonometry, calculus, probability & statics, complex analysis to Fourier transform & LaPlace transforms] or experimental framework stating all relevant assumptions. iv. Formulate the engineering problem into an engineering model [using relevant laws and equations from engineering and science areas) stating all relevant assumptions.	Non ABET Outcome (8) An ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics.
	2. Solve the problems Given an engineering problem that has been formulated, students are able to: i. Solve the resulting engineering/mathematical/science formulations analytically.	

numerically, experimentally or through the use of appropriate software or computer program.

ii. Evaluate and interpret the result.

7 **Brief list of topics to be covered**

Introduction and Basic Concepts	5 hrs
Energy, Energy Trans-fer, and General Energy Analysis	4 hrs
Properties of Pure Substances	5 hrs
Energy Analysis of Closed Systems	4 hrs
Mass and Energy Analysis of Control Volumes	7 hrs
The Second Law of Thermodynamics	5 hrs
ENTROPY & Principle of Increase of Entropy	5 hrs
Fuels, combustion, first and second law analysis of reacting systems	4 hrs
Detailed Design – Analysis and Refinement and application to project	5 hrs

***Course numbers in bracket are the old course numbers**

****Required** courses are required of all students in the program, **elective** courses (often referred to as open or free electives) are optional for students, and **selected elective** courses are those for which students must take one or more courses from a specified group. **Please hide all of the row and column lines when done.**

II ASSESSMENT RESULTS FOR CURRENT AND PAST THREE PERIODS

Program Outcomes Assessed in this course

Outcome 1:

An ability to identify, formulate, and solve **engineering problems** by applying principles of engineering, science, and mathematics

Assessment Summary of Class Semester Averages for Outcomes (Should be provided for FALL 2021 through Spring 2022 Assessment Period)

Outcomes	8
Semester	Semester Class Average (%)
Fall 2021	53.6
Fall 2020	58.7
Spring 2019	Not assessed
Fall 2018	Notassessed
Spring 2018	Not Assessed
Comments on Trend of Data (Improving or deteriorating)	Performance below expected average

*Expected Semester Class Average = 70% (or as defined by the program)

Ideal Semester Class Average =75% (or as defined by the program)

End of Semester Course Assessment Reports FALL 2021 and Last Three Assessment Periods.

Each summary contains the following Information

1. Performance Statistics

- Total number of students in class
- The class average performance (**stated as %**) in each course outcome assessed in this class and the **two previous times course was assessed**.
- The acceptable class average for the class in each outcome area as set by your Department.
- Percentage of students who scored below the expected average in each outcome.

2. Implementation Summary

- Brief summary of plans implemented during the semester based on last assessment report

3. Perceived Problems

- Instructor's **critical evaluation** of perceived problems that affected students' performance. **Realistic problems should be identified throughout the semester and summarized in this section of the report.**

4. New Plans for Addressing Problems

- Instructor's plans for addressing the perceived problems the next time the class is taught. **These should be specific enough for another instructor to implement. Most of these should be things that, you, the instructor can implement to help students to improve. Be creative.**

5. Overall Trend over last three assessment periods

- Instructors summary of overall performance trend for each outcome measured over the last three periods.

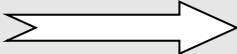
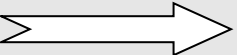
5. Were Expectations Met?

- Answer **YES** if the **class average was above the expected average** and the **stated percentage of students** scored at or above the expected average, else answer **NO**.

Table 2.1 END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
MCEG 2013-P01 THERMODYNAMICS I
FALL 2021 SEMESTER

Report Prepared by: Dr. Paul O. Biney

Report Date: December 20, 2021

Semester	Analysis Type	Number of Students	Outcome 8 An ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics		
			Expected Average	Class Average	% Students Above Expected Average
Fall 2021	Direct	23	70	56.8	23.8
Spring 2021	Direct	26	70	58.6	26.9
Fall 2020	Direct	13	70	58.7	46.2
Implementation Summary			Detailed Class notes were prepared from the Text book and made available through e-course. Review questions were provided to students to answer as they read the notes to gain fundamental understanding. Frequent quizzes were given.		
Perceived Problems			The major problems were: 1. Students found it difficult to understand the fundamentals even though the course was taught at the fundamental level. It appears that the students did not understand the fundamentals. 2. Students did not appear to learn from day to day because they were unable to answer the same fundamental questions on several successive Formative QUIZZES.		
Plans for Addressing Problems			The following is recommended for implementation: All of the Pre-Class reading assignments will be transformed to pre-class reading quiz that is a multiple choice or numeric answer question that would automatically be graded on Canvas as a pre-concepts evaluation and then discussed in the beginning of class to reinforce understanding. Only about 40 % of the pre-class reading questions were converted into pre-class reading quiz, but recommendation is to convert all the questions to pre-class reading quiz in the Spring 2022 semester. Then at last 10 minutes of the class will be used to test students' post understanding of the same concepts in a formative quiz to be conducted on Canvas each class day or at least once a week. Adopt the new FASCIAL teaching approach developed and funded by NSF in this course starting Spring 2022 semester		
Overall Trend over Periods			Performance has been below 60 % in the past few semesters with not much improvement. Assessed only on TaskStream in previous semesters.		
Were Expectations Met?	Average $\geq 70\%$? and $\geq 70\%$ students avg. $\geq 70\%$?		NO		

**THERMODYNAMICS I
FALL 2021**

Title of Assignment: TEST 1

**THERMODYNAMICS I
FALL 2021
TOPICS COVERED IN TEST 1**

Test 1 covered the following topics:

- 1. Introduction and Basic Concepts**
- 2. Energy, Energy Trans-fer, and General Energy Analysis**
- 3. Properties of Pure Substances**

**SAMPLE TEST QUESTIONS, SOLUTION,
AND GRADING SCHEME FOR TEST 1**

FALL 2021 TEST 1 PART A
Master Solution & Grading Scheme

Test 1 Part A

Answer all Questions directly on the question sheets

Show all calculations directly on the question sheets

UPLOAD YOUR WORK ON E-COURSE BY 8:00 AM on 10/19/2021

Q1) If a system changed its state from state 1 to state 2, can we calculate the work and the heat transfer if states 1 and 2 are completely known?

- ☐ No, because both states are known
- ☐ Yes, because we know at least one state
- ☐ Yes, because we know the two states
- ☒ No, because we need to know the path
- ☐ None of the options provided is right

Q2) The initial temperature and pressure of a gas in a closed system are $T_1=100\text{ }^\circ\text{C}$, $P_1=250\text{ kPa}$. The gas is compressed isothermally until its final pressure $P_2=500\text{ kPa}$

Which of the statement below is true about the final temperature, T_2 .

- ☐ $T_2 = 200\text{ }^\circ\text{C}$ (double T_1) because the pressure doubled during the process.
- ☐ $T_2=50\text{ }^\circ\text{C}$ (half of T_1) because of the pressure increase.
- ☐ T_2 cannot be determined because there is not enough information to determine it.
- ☒ $T_2=100\text{ }^\circ\text{C}$ for this process
- ☐ We need to know the volume before we can calculate the final temperature

Q3) The temperatures at locations A and B inside a system are $50\text{ }^\circ\text{C}$ and 50°C respectively one hour ago. The temperatures at locations A and B now are $80\text{ }^\circ\text{C}$ and $80\text{ }^\circ\text{C}$ respectively. Which of the following statements is true about this system.

- ☐ The system is uniform and steady
- ☐ The system is not uniform and it is not steady
- ☒ The system is uniform but not steady
- ☐ The system is steady but not uniform
- ☐ None of the options provided is true

Q4) A gas in a piston cylinder arrangement undergoes a polytropic process from $P_1=770$ kPa, $V_1=0.25$ m³ to a final pressure $P_2=150$ kPa. if the polytropic index, $n=1.22$, what will be the final volume in m³?

$$P_1 V_1^{1.22} = P_2 V_2^{1.22}$$

$$V_2 = V_1 \left(\frac{P_1}{P_2} \right)^{\frac{1}{1.22}} = (0.25 \text{ m}^3) \left(\frac{770 \text{ kPa}}{150 \text{ kPa}} \right)^{\frac{1}{1.22}}$$

$$V_2 = 0.9555 \text{ m}^3$$

Q5) 5 kg of gas in a **closed rigid vessel** of volume 0.25 m³ is heated from $P_1=200$ kPa, $T_1=25$ °C to a temperature of $T_2=500$ °C. Determine the final specific volume, v_2 , in m³/kg.

Since we have a rigid closed system

$$V_2 = V_1$$

$$\text{But } v_1 = \frac{V}{m} = \frac{0.25 \text{ m}^3}{5 \text{ kg}} = 0.05 \text{ m}^3/\text{kg}$$

$$\text{Thus } v_2 = v_1 = 0.05 \text{ m}^3$$

Q6) 550 kJ of work goes into a closed system while the system loses 100kJ of heat from one surface and loses 150 kJ of heat from a second surface. If the initial internal energy of the system was 700 kJ, what is the final internal energy of the system?

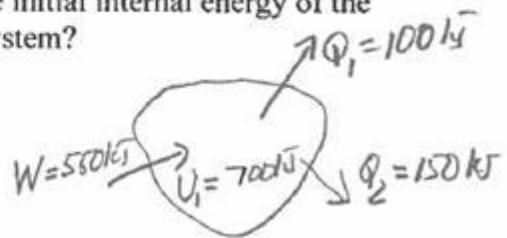
$$E_{in} - E_{out} = U_2 - U_1 \quad \Delta KE = \Delta PE = 0$$

$$W - (Q_1 + Q_2) = U_2 - U_1$$

$$U_2 = W - (Q_1 + Q_2) + U_1$$

$$U_2 = 550 \text{ kJ} - (100 + 150) \text{ kJ} + 700 \text{ kJ}$$

$$U_2 = 1000 \text{ kJ}$$



Q7) A motor drives a pulley that hoists a mass of 1000 kg through a height of 80 m. if $g=9.8$ m/s² and the efficiency of the pulley system is 77%, what energy must be supplied to the motor.

$$m = 1000 \text{ kg} \quad H = 80 \text{ m}$$

$$E_{\text{out}} = mgh = (1000 \text{ kg})(9.8 \text{ m/s}^2)(80 \text{ m}) = 784,000 \text{ J}$$

$$\eta = \frac{E_{\text{out}}}{E_{\text{in}}} \Rightarrow E_{\text{in}} = \frac{E_{\text{out}}}{\eta}$$

$$E_{\text{in}} = \frac{784,000 \text{ J}}{0.77} = 1,018,181 \text{ J}$$

$$\therefore E_{\text{in}} = 1,018.18 \text{ kJ}$$

Q8) Refrigerant 134a is at a temperature of 20 °C and a specific volume of 0.23373 m³/kg. Determine the specific internal energy u , of the refrigerant in kJ/kg

$$\text{At } 20^\circ\text{C} \quad v_f = 0.0008160 \text{ m}^3/\text{kg}, \quad v_g = 0.036012 \text{ m}^3/\text{kg}$$

$v > v_g$, thus we have superheated vapor

From the superheated table for R134a, at 20°C, $v = 0.23373$

$$u = 248.81 \text{ kJ/kg}$$

Q9) For the steam at a Pressure of 10 MPa and specific volume of 0.0011200 m³/kg, find the specific internal energy, u , in kJ/kg.

$$\text{At } P = 10 \text{ MPa} \approx 10,000 \text{ kPa} \quad v_f = 0.001452 \text{ m}^3/\text{kg}, \quad v_g = 0.018028 \text{ m}^3/\text{kg}$$

$v < v_f$ thus, compressed liquid

From compressed liquid Tables

$$\text{at } P = 10 \text{ MPa}, \quad v = 0.0011200$$

$$u = 756.48 \text{ kJ/kg}$$

Q10) Water is at a temperature of 200°C and specific internal energy, $u=1750 \text{ kJ/kg}$. What is the value of its specific enthalpy, h in kJ/kg ?

At $T = 200^\circ\text{C}$ $u_f = 850.46 \frac{\text{kJ}}{\text{kg}}$, $u_g = 2594.2 \frac{\text{kJ}}{\text{kg}}$

u is between u_f & u_g , thus saturated mixture

$$x = \frac{u - u_f}{u_{fg}} = \frac{(1750 - 850.46) \text{ kJ/kg}}{(1743.7) \text{ kJ/kg}} = 0.5159$$

$$h = h_f + x h_{fg} = 852.26 \frac{\text{kJ}}{\text{kg}} + (0.5159)(1439.8) \frac{\text{kJ}}{\text{kg}}$$

$$h = 1852.9 \text{ kJ/kg}$$

Q11) A gas in a closed system is heated from $T_1 = 150^\circ\text{C}$ to a final state where $T_2 = 750^\circ\text{C}$

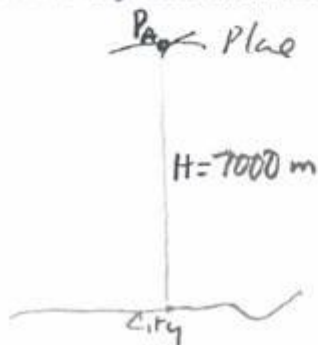
What is the temperature change of this gas in $^\circ\text{R}$?

$$\Delta T ^\circ\text{C} = (750 - 150)^\circ\text{C} = 600^\circ\text{C}$$

$$\Delta T ^\circ\text{F} = 1.8 (\Delta T ^\circ\text{C}) = (1.8)(600) = 1080 ^\circ\text{F}$$

$$\Delta T ^\circ\text{R} = \Delta T ^\circ\text{F} = 1080 ^\circ\text{R}$$

Q12) The pilot of an airplane reads an absolute pressure of 50 kPa at an altitude of 7000 m above a city. if the average density of air is 0.95 kg/m^3 , what will be the local atmospheric pressure on the ground in the city in kPa . Assume $g = 9.8 \text{ m/s}^2$



$$P_A + \rho g H = P_{\text{city}}$$

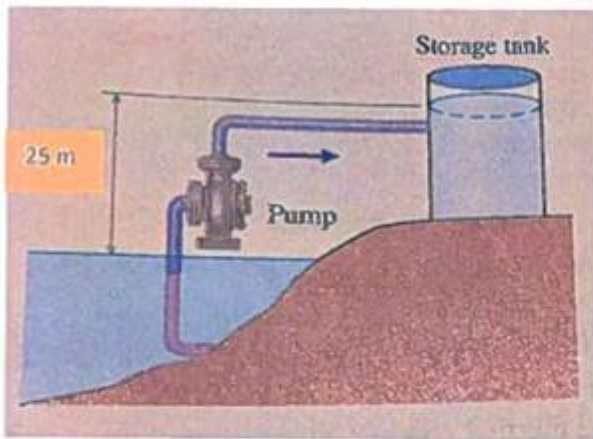
$$P_{\text{city}} = P_A + \rho g H$$

$$P_{\text{city}} = 50 \text{ kPa} + \left(0.95 \frac{\text{kg}}{\text{m}^3}\right) \left(9.8 \frac{\text{m}}{\text{s}^2}\right) \left(\frac{7000}{1000}\right) \text{ k}$$

$$= 115.2 \text{ kPa}$$

PART B QUESTION 3

Water is pumped from a lake to a storage tank located 25 meters above the lake as shown in the Figure. The flow rate of the water pumped is $0.1 \text{ m}^3/\text{s}$. Assume the density of water, $\rho = 1000 \text{ kg/m}^3$ and that $g = 9.81 \text{ m/s}^2$.



- a) Calculate the mass flow rate of the water in kg/s .

$$\text{Volume Flow rate } Q = 0.1 \text{ m}^3/\text{s}, \quad \rho = 1000 \text{ kg/m}^3$$
$$\dot{m} = \rho Q = (1000 \text{ kg/m}^3)(0.1 \text{ m}^3/\text{s}) = 100 \text{ kg/s}$$

$7\frac{1}{2}$

- b) Calculate the specific energy, e , delivered to the water by the pump in kJ/kg .

$$e = gH$$
$$= (9.81 \text{ m/s}^2)(25 \text{ m})$$
$$= 245.25 \frac{\text{J}}{\text{kg}}$$

$7\frac{1}{2}$

- c) Calculate the power output from the pump to the water in kW

$$P = \dot{E} = \dot{m}e$$
$$= (100 \text{ kg/s}) \left(245.25 \frac{\text{J}}{\text{kg}} \right) \frac{1 \text{ kW}}{1000 \text{ J}}$$
$$P = 24.53 \text{ kW}$$

$7\frac{1}{2}$

- d) Calculate the power input to the motor pump system in kW if the efficiency of the pump-motor system is 75%

$$\eta = \frac{P_{\text{out}}}{P_{\text{in}}} \Rightarrow P_{\text{in}} = \frac{P_{\text{out}}}{\eta}$$
$$P_{\text{in}} = \frac{24.53 \text{ kW}}{0.75}$$
$$= 32.7 \text{ kW}$$

$7\frac{1}{2}$

ABOVE AVERAGE

Sample Student Solution

$$\frac{67\frac{1}{2}}{70}$$

$$67\frac{1}{2} + 28 = (95\frac{1}{2} W)$$

Group 4: Tyson Morris, Tyler Rhodes
Josh Jones, Yafet Tekie,
Zack Taylor

Test 1 Part A

Answer all Questions directly on the question sheets

Show all calculations directly on the question sheets

UPLOAD YOUR WORK ON E-COURSE BY 8:00 AM on 10/19/2021

Q1) If a system changed its state from state 1 to state 2, can we calculate the work and the heat transfer if states 1 and 2 are completely known?

- ☐ No, because both states are known
- ☐ Yes, because we know at least one state
- ☐ Yes, because we know the two states
- ☒ No, because we need to know the path ✓ 5
- ☐ None of the options provided is right

Q2) The initial temperature and pressure of a gas in a closed system are $T_1=100^\circ\text{C}$, $P_1=250$ kPa. The gas is compressed isothermally until its final pressure $P_2=500$ kPa

Which of the statement below is true about the final temperature, T_2 .

- ☐ $T_2 = 200^\circ\text{C}$ (double T_1) because the pressure doubled during the process.
- ☐ $T_2=50^\circ\text{C}$ (half of T_1) because of the pressure increase.
- ☐ T_2 cannot be determined because there is not enough information to determine it.
- ☒ $T_2=100^\circ\text{C}$ for this process ✓ 5
- ☐ We need to know the volume before we can calculate the final temperature

Q3) The temperatures at locations A and B inside a system are 50°C and 50°C respectively one hour ago. The temperatures at locations A and B now are 80°C and 80°C respectively. Which of the following statements is true about this system.

- ☐ The system is uniform and steady
- ☐ The system is not uniform and it is not steady
- ☒ The system is uniform but not steady ✓ 5
- ☐ The system is steady but not uniform
- ☐ None of the options provided is true

Q4) A gas in a piston cylinder arrangement undergoes a polytropic process from $P_1=770$ kPa, $V_1=0.25$ m³ to a final pressure $P_2=150$ kPa. if the polytropic index, $n=1.22$, what will be the final volume in m³?

$$P_1 V_1^n = P_2 V_2^n$$

$$(770)(0.25)^{1.22} = 150 V_2^{1.22}$$

$$0.946 = V_2^{1.22}$$

$$0.956 = V_2$$

$$\boxed{0.956 \text{ m}^3}$$

Q5) 5 kg of gas in a closed rigid vessel of volume 0.25 m³ is heated from $P_1=200$ kPa, $T_1=25$ °C to a temperature of $T_2=500$ °C. Determine the final specific volume, v_2 , in m³/kg.

$$v_1 = \frac{V}{m} = \frac{0.25}{5} = \boxed{0.05 \text{ m}^3/\text{kg}}$$

Q6) 550 kJ of work goes into a closed system while the system loses 100kJ of heat from one surface and loses 150 kJ of heat from a second surface. If the initial internal energy of the system was 700 kJ, what is the final internal energy of the system?

$$700 + 550 - 100 - 150 = \boxed{1000 \text{ kJ}}$$

Show Equation



Q7) A motor drives a pulley that hoists a mass of 1000 kg through a height of 80 m. if $g=9.8$ m/s² and the efficiency of the pulley system is 77 %, what energy must be supplied to the motor.

$$E = mgh$$

$$= (1000)(9.8)(80)$$

$$= 784000$$

$$\text{Efficiency} = \frac{784000}{x}$$

$$0.77 = \frac{784000}{x}$$

$$x = \frac{784000}{0.77}$$

Shaw
equations!

Q8) Refrigerant 134a is at a temperature of 20 °C and a specific volume of 0.23373 m³/kg. Determine the specific internal energy u , of the refrigerant in kJ/kg

$$v_g = 0.025012$$

$v > v_g$, so superheated

u @ 20°C in superheated table:

$$u = 248.81 \text{ kJ/kg}$$

Q9) For the steam at a Pressure of 10 MPa and specific volume of 0.0011200 m³/kg, find the specific internal energy, u , in kJ/kg.

$v < v_g$, so compressed

$$v @ 10 \text{ MPa} = 0.0011200$$

$$u = 756.48 \text{ kJ/kg}$$

Q10) Water is at a temperature of 200 °C and specific internal energy, $u=1750$ kJ/kg. What is the value of its specific enthalpy, h in kJ/kg?

$$u = u_g + x u_{fg}$$

$$1750 = 850 + x(1743.7)$$

$$900 = 1743.7x$$

$$0.516 = x$$

10

$$h = h_g + x h_{fg}$$

$$h = 852.26 + (0.516)(1939.8)$$

$$h = 1853.48 \text{ kJ/kg}$$

Q11) A gas in a closed system is heated from $T_1=150$ °C to a final state where $T_2=750$ °C.

What is the temperature change of this gas in °R?

$$\Delta R = 1.8 \Delta C$$

$$\Delta R = 1.8(600)$$

$$\Delta R = 1080$$

$$\Delta C = T_2 - T_1 = 750 - 150 = 600$$

Units

Q12) The pilot of an airplane reads an absolute pressure of 50 kPa at an altitude of 7000 m above a city. If the average density of air is 0.95 kg/m³, what will be the local atmospheric pressure on the ground in the city in kPa. Assume $g=9.8$ m/s².

$$P = P_{atm} + \rho g h$$

$$P = 50 + (0.95)(9.8)(7000/1000)$$

$$P = 115.237 \text{ kPa}$$

$$\rho = 0.95 \text{ kg/m}^3$$

$$g = 9.81 \text{ m/s}^2$$

84
90

W 28
30

FALL 2021 TEST 1 PART B
ANSWER ALL QUESTIONS

28 1/2
30

PART B QUESTION 1

A piston cylinder device contains 0.005 m³ of liquid water and 0.8 m³ of water vapor in equilibrium at 1000 kPa. Heat is transferred at constant pressure until the final temperature, T₂=300 °C. Determine:

- a) The initial temperature, T₁ in °C

$T_{@1000kPa} = 179.88^{\circ}C$

B 25 x 1411

- b) The initial mass of liquid, m_f, the initial mass of vapor, m_g, and the initial total mass of the mixture, m_T

$v = \frac{V}{m}$

$m_f = \frac{V_f}{v_f} = \frac{0.005}{0.001127} = 4.437 \text{ kg} = \text{initial mass of liquid}$

$m_g = \frac{V_g}{v_g} = \frac{0.8}{0.19436} = 4.116 \text{ kg} = \text{initial mass of vapor}$

$m_{\text{total}} = m_g + m_f = 4.116 + 4.437 = 8.553 \text{ kg}$

4
4

- c) The quality, x, of the mixture at state 1

$v = \frac{V}{m} = \frac{0.805}{8.553} = 0.094 \text{ m}^3/\text{kg}$

$v = v_f + x v_{fg}$

$0.094 = 0.001127 + x(0.193233)$

$0.481 = x$

$v_{fg} = v_g - v_f$
 $v_{fg} = 0.19436 - 0.001127$
 $v_{fg} = 0.193233$

- d) The specific volume, v, of the mixture at state 1

$v = \frac{V}{m} = \frac{0.805}{8.553} = 0.094 \text{ m}^3/\text{kg}$

4

- e) The final pressure, P₂ in kPa, and the final specific volume, v₂ in m³/kg

isobaric, so $P_2 = P_1 = 1000 \text{ kPa}$

at 1000 kPa and 300 °C on superheated table, $v_2 = 0.25799 \text{ m}^3/\text{kg}$

4

f) The final total volume, V_2 in m^3

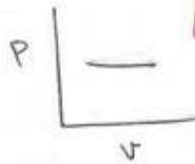
$$v = \frac{V}{m}$$

$$0.25799 = \frac{V}{8.653}$$

$$\boxed{2.207 \text{ m}^3 = V_2}$$

4

g) Show the process on a P-v diagram



Incomplete!!
1

PART B QUESTION 2

Steam is at a pressure, $P=20$ MPa and temperature $T=500$ °C. The specific gas constant for steam is $R=0.4615$ kJ/kg-K. For water, the critical pressure, $P_c=22.06$ MPa and the critical temperature $T_c=647.1$ K

1. Determine the specific volume of the steam using the steam table.

$$v = 0.012721 \text{ m}^3/\text{kg}$$

explain

26/30

2. Determine the specific volume of the steam assuming the steam behaves as an ideal gas

$$P_r = RT$$
$$(20,000) v = (0.4615)(773)$$
$$v = 0.178 \text{ m}^3/\text{kg}$$

$$500 + 273 = 773$$

3. Compute the reduce pressure, P_r and the reduced temperature, T_r .

$$P_r = \frac{P}{P_c} = \frac{20}{22.06} = 0.907 \text{ MPa}$$

$$T_r = \frac{T}{T_c} = \frac{773}{647.1} = 1.195 \text{ K}$$

4. Using the values of P_r and T_r computed, use the compressibility chart to estimate the value of the compressibility factor, Z

$$Z = 0.815$$

5. Compute the specific volume of the steam based on the Z value obtained from the compressibility chart.

$$Z = \frac{Pv}{RT}$$

$$v = \frac{ZRT}{P}$$

$$v = \frac{(0.815)(0.4615)(773)}{20,000} = 0.0145 \text{ m}^3/\text{kg}$$

AVERAGE

Score for this quiz: 60 out of 70
Submitted Oct 14 at 11:59pm
This attempt took 949 minutes.

60+23
=83%

Question 1

5 / 5 pts

If a system changed its state from state 1 to state 2, can we calculate the work and the heat transfer if states 1 and 2 are completely known?

- ☐ None of the options provided is right
- ☐ No, because both states are known
- ☒ No, because we need to know the path
- ☐ Yes, because we know the two states
- ☐ Yes, because we know at least one state

Correct!

Question 2

5 / 5 pts

The initial temperature and pressure of a gas in a closed system are $T_1=100\text{ }^{\circ}\text{C}$, $P_1=250\text{ kPa}$. The gas is compressed isothermally until its final pressure $P_2=500\text{ kPa}$

Which of the statement below is true about the final temperature, T_2 .

- ☐ $T_2 = 200\text{ }^{\circ}\text{C}$ (double T_1) because the pressure doubled during the process.
- ☐ $T_2=50\text{ }^{\circ}\text{C}$ (half of T_1) because of the pressure increase.
- ☒ $T_2=100\text{ }^{\circ}\text{C}$ for this process
- ☐ We need to know the volume before we can calculate the final temperature
- ☐ T_2 cannot be determined because there is not enough information to determine it

Correct!

Question 3

5 / 5 pts

The temperatures at locations A and B inside a system are 50 °C and 50°C respectively one hour ago. The temperatures at locations A and B now are 80 °C and 80 °C respectively. Which of the following statements is true about this system.

- ☐ None of the options provided is true
- ☐ The system is not uniform and it is not steady
- ☐ The system is steady but not uniform
- ☒ The system is uniform but not steady
- ☐ The system is uniform and steady

Correct!

Question 4

5 / 5 pts

A gas in a piston cylinder arrangement undergoes a polytropic process from $P_1=770$ kPa, $V_1=0.25$ m³ to a final pressure $P_2=150$ kPa. if the polytropic index, $n=1.22$, what will be the final volume in m³?

Correct!

0.9555

Correct Answers

0.956 (with margin: 0.02)

Question 5

5 / 5 pts

5 kg of gas in a **closed rigid vessel** of volume 0.25 m^3 is heated from $P_1=200 \text{ kPa}$, $T_1=25^\circ\text{C}$ to a temperature of $T_2=500^\circ\text{C}$. Determine the final specific volume, v_2 , in m^3/kg .

Correct!

0.05

Correct Answers

0.05 (with margin: 0.005)

0 (with margin: 0)

0 (with margin: 0)

0 (with margin: 0)

Question 6

10 / 5 pts

550 kJ of work goes into a closed system while the system loses 100 kJ of heat from one surface and loses 150 kJ of heat from a second surface. If the initial internal energy of the system was 700 kJ, what is the final internal energy of the system?

Correct!

1,000

Correct Answers

1,000 (with margin: 1)

Question 7

10 / 5 pts

5. A motor drives a pulley that hoists a mass of 1000 kg through a height of 80 m. if $g=9.8 \text{ m/s}^2$ and the efficiency of the pulley system is 77 %, what energy must be supplied to the motor.

You Answered

Question 8

5 / 5 pts

Refrigerant 134a is at a temperature of 20 °C and a specific volume of 0.23373 m³/kg. Determine the specific internal energy u , of the refrigerant in kJ/kg

Correct!

248.81

Correct Answers

248.81 (with margin: 0.01)

Question 9

5 / 5 pts

For the steam at a Pressure of 10 MPa and specific volume of 0.0011200 m³/kg, find the specific internal energy, u , in kJ/kg.

Correct!

756.48

Correct Answers

756.48 (with margin: 0.1)

Question 10

0 / 10 pts

Water is at a temperature of 200 °C and specific internal energy, $u=1750$ kJ/kg. What is the value of its specific enthalpy, h in kJ/kg?

You Answered

1,946.4

Correct Answers

1,852.9 (with margin: 10)

Question 11

5 / 5 pts

A gas in a closed system is heated from $T_1=150$ °C to a final state where $T_2=750$ °C

What is the temperature change of this gas in °R?

Correct!

1,080

Correct Answers

1,080 (with margin: 10)

Unanswered

Question 12

0 / 5 pts

The pilot of an airplane reads an absolute pressure of 50 kPa at an altitude of 7000 m above a city. if the average density of air is 0.95 kg/m^3 , what will be the local atmospheric pressure on the ground in the city in kPa. Assume $g=9.8 \text{ m/s}^2$

You Answered

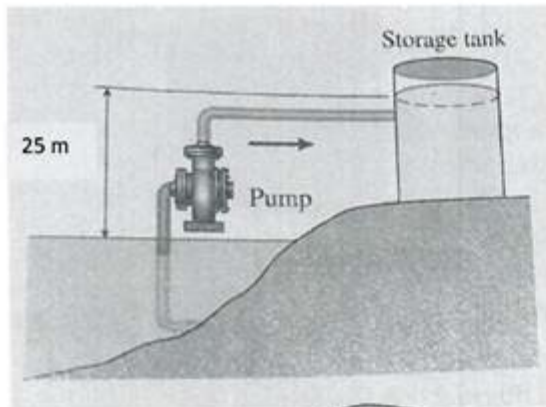
Correct Answers

- 0 (with margin: 0)
- 0 (with margin: 0)
- 105.2 (with margin: 2)
- 0 (with margin: 0)

PART B QUESTION 3

Water is pumped from a lake to a storage tank located 25 meters above the lake as shown in the Figure. The flow rate of the water pumped is $0.1 \text{ m}^3/\text{s}$. Assume the density of water, $\rho = 1000 \text{ kg/m}^3$ and that $g = 9.81 \text{ m/s}^2$.

- Calculate the mass flow rate of the water in kg/s .
- Calculate the specific energy, e , delivered to the water by the pump in kJ/kg .
- Calculate the power output from the pump to the water in kW .
- Calculate the power input to the motor pump system in kW if the efficiency of the pump-motor system is 75%.



$$\dot{V} = 0.1 \text{ m}^3/\text{s} \quad \rho = 1000 \text{ kg/m}^3 \quad g = 9.81 \text{ m/s}^2$$

$$\dot{m} = \rho \dot{V} = 1000 \times 0.1 = 100 \text{ kg/s}$$

$$e = \dot{m} g h = 100 \times 9.81 \times 25 = 24.525 \text{ kJ/kg}$$

$$\dot{W} = \dot{m} e = 100 \times 24.525 = 2452.5 \text{ W}$$

$$P = \frac{2452.5}{1000} = 2.4525 \text{ kW}$$

$$P_{\text{input}} = \frac{2.4525}{0.75} = 3.27 \text{ kW}$$

2/12/24

BELOW AVERAGE

30 + 16 = 46 %

Score for this quiz: 30 out of 70

Submitted Oct 14 at 9:02am

This attempt took 47 minutes.

Question 1

0 / 5 pts

If a system changed its state from state 1 to state 2, can we calculate the work and the heat transfer if states 1 and 2 are completely known?

You Answered

☒ Yes, because we know at least one state

☐ Yes, because we know the two states

☐ No, because both states are known

☐ None of the options provided is right

Correct Answer

☐ No, because we need to know the path

Question 2

5 / 5 pts

The initial temperature and pressure of a gas in a closed system are $T_1 = 100^\circ\text{C}$, $P_1 = 250\text{ kPa}$. The gas is compressed isothermally until its final pressure $P_2 = 500\text{ kPa}$

Which of the statement below is true about the final temperature, T_2 .

☐ T_2 cannot be determined because there is not enough information to determine it.

☐ We need to know the volume before we can calculate the final temperature

Correct!

☒ $T_2 = 100^\circ\text{C}$ for this process

☐ $T_2 = 50^\circ\text{C}$ (half of T_1) because of the pressure increase.

☐ $T_2 = 200^\circ\text{C}$ (double T_1) because the pressure doubled during the process.

Question 3

0 / 5 pts

The temperatures at locations A and B inside a system are 50 °C and 50°C respectively one hour ago. The temperatures at locations A and B now are 80 °C and 80 °C respectively. Which of the following statements is true about this system.

Correct Answer

☐ The system is uniform but not steady☐ The system is uniform and steady

You Answered

☒ The system is steady but not uniform☐ None of the options provided is true☐ The system is not uniform and it is not steady

Question 4

5 / 5 pts

A gas in a piston cylinder arrangement undergoes a polytropic process from $P_1=770$ kPa, $V_1=0.25$ m³ to a final pressure $P_2=150$ kPa. if the polytropic index, $n=1.22$, what will be the final volume in m³?

Correct!

0.95

Correct Answers

0.956 (with margin: 0.02)

Question 5

0 / 5 pts

5 kg of gas in a **closed rigid vessel** of volume 0.25 m³ is heated from $P_1=200$ kPa, $T_1= 25$ °C to a temperature of $T_2=500$ °C. Determine the final specific volume, v_2 , in m³/kg.

You Answered

0.25

Correct Answers

0.05 (with margin: 0.005)

0 (with margin: 0)

0 (with margin: 0)

0 (with margin: 0)

Question 6

10 / 5 pts

550 kJ of work goes into a closed system while the system loses 100kJ of heat from one surface and loses 150 kJ of heat from a second surface. If the initial internal energy of the system was 700 kJ, what is the final internal energy of the system?

Correct!

1,000

Correct Answers

1,000 (with margin: 1)

Unanswered

Question 7

0 / 5 pts

5. A motor drives a pulley that hoists a mass of 1000 kg through a height of 80 m. if $g=9.8 \text{ m/s}^2$ and the efficiency of the pulley system is 77 %, what energy must be supplied to the motor.

Correct Answer

☐

Question 8

5 / 5 pts

Refrigerant 134a is at a temperature of 20°C and a specific volume of $0.23373 \text{ m}^3/\text{kg}$. Determine the specific internal energy u , of the refrigerant in kJ/kg

Correct!

248.81

Correct Answers

248.81 (with margin: 0.01)

Question 9

5 / 5 pts

For the steam at a Pressure of 10 MPa and specific volume of $0.0011200 \text{ m}^3/\text{kg}$, find the specific internal energy, u , in kJ/kg.

Correct!

756.48

Correct Answers

756.48 (with margin: 0.1)

Question 10

0 / 10 pts

Water is at a temperature of 200°C and specific internal energy, $u=1750 \text{ kJ/kg}$. What is the value of its specific enthalpy, h in kJ/kg?

You Answered

1,939.8

Correct Answers

1,852.9 (with margin: 10)

Question 11

0 / 5 pts

A gas in a closed system is heated from $T_1=150^\circ\text{C}$ to a final state where $T_2=750^\circ\text{C}$

What is the temperature change of this gas in $^\circ\text{R}$?

You Answered

1,539.67

Correct Answers

1,080 (with margin: 10)

Unanswered

Question 12

0 / 5 pts

The pilot of an airplane reads an absolute pressure of 50 kPa at an altitude of 7000 m above a city. if the average density of air is 0.95 kg/m^3 , what will be the local atmospheric pressure on the ground in the city in kPa. Assume $g=9.8 \text{ m/s}^2$

You Answered

Correct Answers

- 0 (with margin: 0)
- 105.2 (with margin: 2)
- 0 (with margin: 0)
- 0 (with margin: 0)

FALL 2021 TEST 1 PART B

ANSWER ANY 2 QUESTIONS

PART B QUESTION 1

$$30 + 16 = 46\%$$

A piston cylinder device contains 0.005 m^3 of liquid water and 0.8 m^3 of water vapor in equilibrium at 1000 kPa. Heat is transferred at constant pressure until the final temperature, $T_2=300^\circ\text{C}$. Determine:

- The initial temperature, T_1 in $^\circ\text{C}$
- The initial mass of liquid, m_f , the initial mass of vapor, m_g , and the initial total mass of the mixture, m
- The quality, x , of the mixture at state 1
- The specific volume, v , of the mixture at state 1
- The final pressure, P_2 is kPa, and the final specific volume, v_2 is m^3/kg
- The final total volume, V_2 is m^3
- Show the process on a P-v diagram

PART B QUESTION 2

Steam is at a pressure, $P=20$ MPa and temperature $T=500$ °C. The specific gas constant for steam is $R=0.4615$ kJ/kg·K. For water, the critical pressure, $P_c=22.06$ MPa and the critical temperature $T_c=647.1$ K.

1. Determine the specific volume of the steam using the steam table.
2. Determine the specific volume of the steam assuming the steam behaves as an ideal gas.
3. Compute the reduced pressure, P_r and the reduced temperature, T_r .
4. Using the values of P_r and T_r computed, use the compressibility chart to estimate the value of the compressibility factor, Z .
5. Compute the specific volume of the steam based on the Z value obtained from the compressibility chart.

1. specific volume : 0.04793 ✓ 6

2. $Pv = RT$, $20 \times 10^6 = 0.4615 \times 1000 \times 773.15$ ✓ 6

3. $\frac{20}{22.06} = \frac{0.4615 \times 1000 \times 773.15}{22.06 \times 10^6} = 1.998 \times 10^{-3}$ ✓ 6

4. 0.5 ✓ 4

16/30

**THERMODYNAMICS I
FALL 2021**

Title of Assignment: TEST 2

TOPICS COVERED IN TEST 2

Test 2 covered the following topics:

- 1. Energy Analysis of Closed Systems**
- 2. Mass and Energy Analysis of Control Volumes**
- 3. The Second Law of Thermodynamics**

**SAMPLE TEST QUESTIONS, SOLUTION,
AND GRADING SCHEME FOR TEST 2**

FALL 2021 TEST 1 PART A
Master Solution & Grading Scheme
Fall 2021 Thermodynamics I Test 2 Part A
Answer All Questions

1. Air in a rigid closed vessel is initially at pressure $P_1=100$ kPa, $V_1=100$ oC. The air is heated to a final temperature $T_2=500$ oC. What the work done in kJ? Air in a rigid closed vessel is initially at pressure $P_1=100$ kPa, $V_1=100$ oC. The air is heated to a final temperature $T_2=500$ oC. What the work done in kJ?

Rigid Vessel. Volume is constant

$$W = \int P dV = 0 \text{ since } dV = 0 \text{ for rigid vessel}$$

2. Refrigerant R-134a at a temperature of 50 °C has a specific volume, $v=0.12766$ m³/kg. The pressure in MPa is

$$v_f = \frac{1}{2}(0.0008997 + 0.0009151) = 0.0009074$$

$$v_g = \frac{1}{2}(0.015951 + 0.014276) = 0.01511$$

$h > h_g$, thus superheated vapor

$$P_2 = 0.29 \text{ MPa}$$

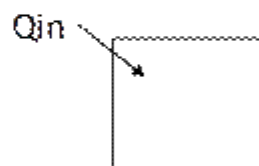
3. Air in a rigid closed vessel is initially at $P_1=100$ kPa, $T_1=390$ K, $V_1=12.5$ m³. The air is heated to a final temperature $T_2=770$ K. Assume the air is an ideal gas and that $R=0.287$ kJ/kg·K and $c_v=0.718$ kJ/kg·K. The total heat transferred in kJ is

Energy Balance

$$E_{in} - E_{out} = E_2 - E_1$$

$$Q_{in} = m(u_2 - u_1)$$

$$Q = mc_v(T_2 - T_1)$$



Find m from ideal gas equation

$$P_1 V_1 = m R T_1 \text{ Thus } m = P_1 V_1 / (R T_1) = (100 \text{ kPa})(12.5 \text{ m}^3) / [(0.287 \text{ kJ/kg}\cdot\text{K})(390 \text{ K})] = 11.17 \text{ kg}$$

Energy Balance

$$E_{in} - E_{out} = E_2 - E_1 \quad \text{Thus } Q_{in} = m(u_2 - u_1)$$

$$Q_{in} = m c_v (T_2 - T_1) = (11.17 \text{ kg})(0.718 \text{ kJ/kg}\cdot\text{K})(770 - 390) \text{ K} = 3047.6 \text{ kJ}$$

$$Q_{in} = 3,047.6 \text{ kJ} \text{ or By air Tables } 278.93 \text{ kJ/kg, } u_2 = 0.5(568.104 + 576.12) = 568.07$$

$$Q_{in} = m(u_2 - u_1) = 11.17(568.07 - 278.93) = 3229.8 \text{ kJ}$$

4. 250 kJ of work goes into a closed system while the system loses 80 kJ of heat. If the initial internal energy of the system was 300 kJ, what is the final internal energy of the system?

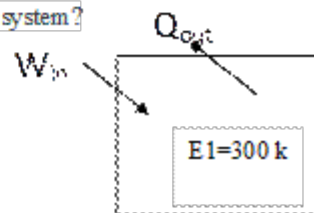
Energy Balance

$$E_{in} - E_{out} = E_2 - E_1$$

$$W_{in} - Q_{out} = E_2 - E_1$$

$$E_2 = W_{in} - Q_{out} + E_1$$

$$= 250 - 80 + 300 = 470 \text{ kJ}$$



1. A crane lifts a bucket of cement with a mass of 450 kg vertically up with a constant velocity of 2 m/s. Assuming $g=9.81 \text{ m/s}^2$, the rate of power in kW used by the crane is

- a) 0.9
b) 4.42
c) **8.83**
d) 8.52
e) 1.8

$$P = mgH/t = mgV$$

$$P = (450 \text{ kg})(9.81 \text{ m/s}^2)(2 \text{ m/s})/1000 = 8.83 \text{ kW}$$

2. As a result of heat transferred to a gas in a system, the temperature changed by 700 K. What is this temperature change in $^{\circ}\text{R}$?

$$\Delta T ^{\circ}\text{F} = \Delta T ^{\circ}\text{R} = 1.8 \Delta T \text{ K} = (1.8)(700) = \mathbf{1260 ^{\circ}\text{R}}$$

3. If m is the mass and h is the specific enthalpy, then the total enthalpy of a system H is given by

- a) $H = h/m$
b) $H = m/h$
f) **$H = mh$**
g) $H = h$
h) None of the above is correct

4. A cylinder/piston contains 2 kg of air at 100 kPa, 20°C . The air is compressed polytropically to a pressure of 900 kPa. Calculate the absolute value of the work required if the polytropic exponent $n = 1.25$. Assume $R = 0.287 \text{ kJ/kg}\cdot\text{K}$. (Hint: First calculate V_1 , and then V_2)

$$T_1 = 20 + 273.15 = 293.15 \text{ K},$$

$$P_1 V_1 = mRT_1, \text{ thus } V_1 = mRT_1/P_1 = (2 \text{ kg})(0.287 \text{ kJ/kg}\cdot\text{K})(293.15 \text{ K})/(100 \text{ kPa})$$

$$V_1 = 1.683 \text{ m}^3$$

$$P_2 V_2^n = P_1 V_1^n, \text{ thus } V_2 = V_1 [P_1/P_2]^{1/n}$$

$$V_2 = (1.683 \text{ m}^3)[100/900]^{1/1.25} \quad V_2 = 0.2901 \text{ m}^3$$

$$W = (P_2 V_2 - P_1 V_1)/(1-n) = [(900 \text{ kPa})(0.2901 \text{ m}^3) - (100 \text{ kPa})(1.683 \text{ m}^3)]/(1-1.25) = \mathbf{-371.4 \text{ kJ}}$$

$W = 371.4 \text{ kJ}$ into system or on system

5. kg of refrigerant R-134a passes through the throttle valve shown. The properties at the inlet are provided on the figure. The refrigerant loses an amount of heat, $Q = 15 \text{ kJ}$ as it flows through the valve. By making an energy balance on the system, the computed value of the enthalpy at the exit state 2, h_2 in kJ/kg

Energy balance gives

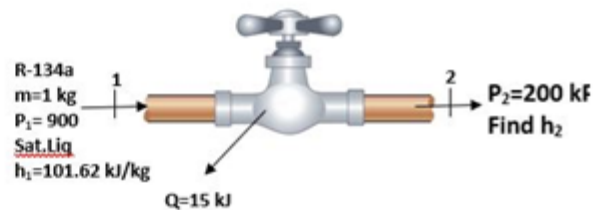
$$E_{in} = E_{out}$$

$$mh_1 = mh_2 + Q$$

$$h_2 = h_1 - Q/m$$

$$h_2 = 101.62 \text{ kJ/kg} - 15 \text{ kJ/kg} = \mathbf{86.62 \text{ kJ/kg}}$$

$$\mathbf{h_2 = 86.62 \text{ kJ/kg}}$$



6. By making an energy balance on the turbine shown in the figure, calculate the power output of the turbine in kW

Energy balance gives

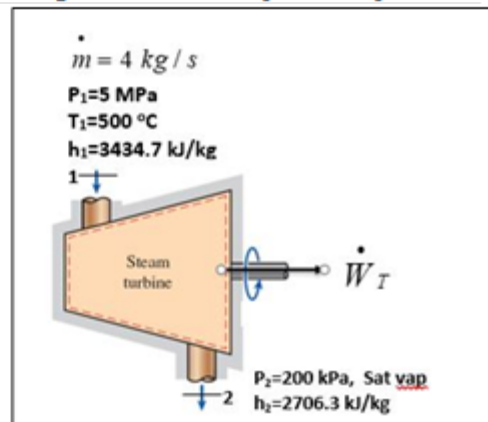
$$E_{in} = E_{out}$$

$$mh_1 = mh_2 + W$$

$$W = m(h_1 - h_2)$$

$$W = (4 \text{ kg/s})(3434.7 - 2706.3)$$

$$\mathbf{W = 2,913.6 \text{ kW}}$$



THERMODYNAMICS I FALL 2021 SEMESTER TEST 2 Part B

ANSWER QUESTION 1 AND ANY 1 OTHER QUESTION

SHOW YOUR CALCULATIONS 11/11/2021

Name of Student (PRINT) Mester Solution

I UNDERSTAND THAT CHEATING OR SEEKING HELP DURING THIS QUIZ WILL RESULT IN "F" GRADE

Student's Signature

QUESTION 1 [25]

The 1.5 m³ rigid tank shown below initially contains air at . The valve connected to the tank is opened allowing air at $P_i=500$ kPa, $T_i=500$ K to enter the tank until the final condition in the tank is $T_2=400$ K, $P_2=350$ kPa at which time the valve is completely closed. For air, assume the gas constant $R=0.287$ kJ/kg-K. Read all properties from the air tables.

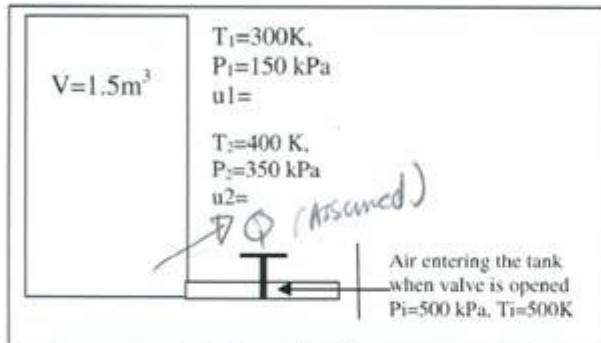


Figure 1

- i. Applying the ideal gas law, calculate the mass of air, m_1 , initially in the tank.

$$\begin{aligned}
 P_1 &= 150 \text{ kPa}, \quad T_1 = 300 \text{ K}, \quad V = 1.5 \text{ m}^3 \\
 P_1 V_1 &= m_1 R T_1 \\
 m_1 &= \frac{P_1 V_1}{R T_1} = \frac{(150 \text{ kPa})(1.5 \text{ m}^3)}{(0.287 \frac{\text{kJ}}{\text{kg-K}})(300 \text{ K})} \\
 m_1 &= 2.613 \text{ kg}
 \end{aligned}
 \quad \left. \vphantom{\begin{aligned} P_1 &= 150 \text{ kPa}, \quad T_1 = 300 \text{ K}, \quad V = 1.5 \text{ m}^3 \\ P_1 V_1 &= m_1 R T_1 \\ m_1 &= \frac{P_1 V_1}{R T_1} = \frac{(150 \text{ kPa})(1.5 \text{ m}^3)}{(0.287 \frac{\text{kJ}}{\text{kg-K}})(300 \text{ K})} \right\} 4$$

- ii. Calculate the final mass of air, m_2 , in the tank.

$$\begin{aligned}
 P_2 &= 350 \text{ kPa}, \quad T_2 = 400 \text{ K}, \quad V_2 = V_1 = 1.5 \text{ m}^3 \quad (\text{rigid tank}) \\
 m_2 &= \frac{P_2 V_2}{R T_2} = \frac{(350 \text{ kPa})(1.5 \text{ m}^3)}{(0.287 \frac{\text{kJ}}{\text{kg-K}})(400 \text{ K})} \\
 m_2 &= 4.573 \text{ kg}
 \end{aligned}
 \quad \left. \vphantom{\begin{aligned} P_2 &= 350 \text{ kPa}, \quad T_2 = 400 \text{ K}, \quad V_2 = V_1 = 1.5 \text{ m}^3 \quad (\text{rigid tank}) \\ m_2 &= \frac{P_2 V_2}{R T_2} = \frac{(350 \text{ kPa})(1.5 \text{ m}^3)}{(0.287 \frac{\text{kJ}}{\text{kg-K}})(400 \text{ K})} \right\} 4$$

- iii. Applying the law of conservation of mass, calculate the total mass of air, m_i , that entered the tank during the process.

$$\left. \begin{aligned} m_i - m_e &= m_2 - m_1 & m_e &= 0 \\ m_i &= m_2 - m_1 \\ &= (4.573 - 2.613) \text{ kg} \\ &= 1.96 \text{ kg} \end{aligned} \right\} 4$$

- iv. Determine the initial and final specific internal energy, u_1 and u_2 of the air in the tank, and the enthalpy h_i at the inlet to the tank / from the air Tables

For air at $T_1 = 300\text{K}$, $u_1 = 214.07 \text{ kJ/kg}$ — 2

For air at $T_i = 500\text{K}$, $h_i = 503.02 \text{ kJ/kg}$ — 2

For air at $T_2 = 400\text{K}$, $u_2 = 286.16 \text{ kJ/kg}$ — 2

- v. Determine the specific enthalpy, h_i , of the air entering the tank from the air Tables —

- vi. Making an energy Balance on the system, Calculate the total heat transfer during the process.

$$\left. \begin{aligned} E_{in} - E_{out} &= E_2 - E_1 \\ m_i h_i - Q &= m_2 u_2 - m_1 u_1 \\ Q &= m_i h_i - (m_2 u_2 - m_1 u_1) \end{aligned} \right\} 3$$

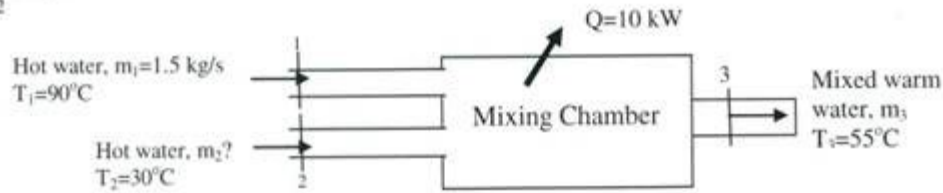
$$\begin{aligned} &= (2.613 \text{ kg})(503.02 \frac{\text{kJ}}{\text{kg}}) - [(4.573)(286.16) - (2.613)(214.07)] \text{ kJ} \\ &= -288.4 \text{ kJ} \end{aligned}$$

$$Q = 288.4 \text{ kJ (into system)} \quad \left. \vphantom{\begin{aligned} &= (2.613 \text{ kg})(503.02 \frac{\text{kJ}}{\text{kg}}) - [(4.573)(286.16) - (2.613)(214.07)] \text{ kJ} \\ &= -288.4 \text{ kJ} \end{aligned}} \right\} 4$$

QUESTION 2 [15]

A hot water stream at 90 °C enters a mixing chamber with a mass flow rate of 1.5 kg/s where it is mixed with a stream of cold water at 30 °C. After mixing, the mixed stream leaves the mixing chamber at 55 °C. Assume kinetic energy and potential energy changes are negligible. The system loses 10 kW of heat. To the surroundings.

Figure 2



- i. Write the conservation of mass equation for the control volume and express the mass flow rate m_3 in terms of the mass flow rates m_1 and m_2

$$\left. \begin{aligned} m_i &= m_e \\ m_1 + m_2 &= m_3 \end{aligned} \right\} 2 \frac{1}{2}$$

Thus $m_3 = m_1 + m_2$

- ii. Determine the specific enthalpies h_1 , h_2 , and h_3 at states 1, 2, and 3 respectively

For water at $T_1 = 90^\circ\text{C}$, $h_1 \approx h_{f \text{ at } 90^\circ\text{C}} = 377.04 \text{ kJ/kg}$

At $T_2 = 30^\circ\text{C}$, $h_2 \approx h_{f \text{ at } 30^\circ\text{C}} = 125.74 \text{ kJ/kg}$

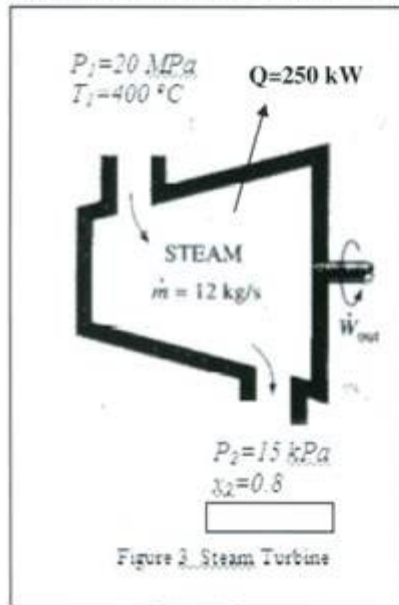
At $T_3 = 55^\circ\text{C}$, $h_3 \approx h_{f \text{ at } 55^\circ\text{C}} = 230.26 \text{ kJ/kg}$

- iii. Applying energy balance on the control volume, determine the mass flow rate of the cold water, m_2 in kg/s

$$\begin{aligned} E_i &= E_e \Rightarrow m_1 h_1 + m_2 h_2 = m_3 h_3 + Q \\ m_1 h_1 + m_2 h_2 &= (m_1 + m_2) h_3 + Q \\ m_2 (h_2 - h_3) &= m_1 (h_3 - h_1) + Q \\ \text{Thus } m_2 &= \frac{m_1 (h_3 - h_1)}{(h_2 - h_3)} + \frac{Q}{(h_2 - h_3)} = 1.5 \left(\frac{230.26 - 377.04}{125.74 - 230.26} \right) + \frac{10 \text{ kW}}{(125.74 - 230.26) \text{ kJ/kg}} \\ m_2 &= 2.011 \text{ kg/s} \end{aligned}$$

QUESTION 3 [15]

Steam flows steadily through the turbine shown in Figure 3. The inlet conditions at state 1 and the outlet conditions at state 2 are shown in the Figure 1. Assume the kinetic and potential energy changes are zero. The turbine loses 250 kW of heat to the surroundings.



Determine

- (i) the specific enthalpy at the inlet, h_1

At $P_1 = 20 \text{ MPa}$
 $T_1 = 400^\circ\text{C}$ we are superheated
 $h_1 = 2816.9 \text{ kJ/kg}$ — 2

- ii) the specific enthalpy at the exit h_2

$$h_2 = h_{f2} + x_2 h_{fg2}$$

$h_{f2} = 225.94 \text{ kJ/kg}$, $h_{fg2} = 2372.3 \text{ kJ/kg}$

$$h_2 = 225.94 + (0.8)(2372.3) = 2123.8 \text{ kJ/kg}$$
 — 3

- (i) By making an energy balance on the turbine, calculate the power output of the turbine in kW.

$$E_{in} = E_{out}$$

$$m h_1 = m h_2 + Q + W$$

$$W = m(h_1 - h_2) - Q$$

$$= (12 \text{ kg/s})(2816.9 - 2123.8) - 250$$

$$\dot{W} = 8,067.4 \text{ kW}$$

ABOVE AVERAGE

85/115 = 74%
Group 5

Fall 2021 Thermodynamics I Test 2 Part A

Answer All Questions

Hunter Evans
Darrin Scott
Jordan Joubert
Manuel Reyes
Safiatou Zamballyre

1. Air in a rigid closed vessel is initially at pressure $P_1=100$ kPa, $V_1=100$ oC. The air is heated to a final temperature $T_2=500$ oC. What the work done in kJ? Air in a rigid closed vessel is initially at pressure $P_1=100$ kPa, $V_1=100$ oC. The air is heated to a final temperature $T_2=500$ oC. What the work done in kJ?

$$P_1=100 \text{ kPa}$$

$$T_1=100^\circ\text{C}$$

$$T_2=500^\circ\text{C}$$

$$Q = W + \Delta U$$

work is 0 kJ because change in volume is 0

2. Refrigerant R-134a at a temperature of 50°C has a specific volume, $v=0.12766$ m³/kg. The pressure in MPa is

41/60

3

$$0.20 \text{ MPa}$$

How?

3. Air in a rigid closed vessel is initially at $P_1=100$ kPa, $T_1=390$ K, $V_1=12.5$ m³. The air is heated to a final temperature $T_2=770$ K. Assume the air is an ideal gas and that $R=0.287$ kJ/kg and $c_v=0.718$ kJ/kg-K. The total heat transferred in kJ is

$$n = \frac{PV}{RAT} = \frac{100 \cdot 12.5}{0.287 \cdot (770 - 390)} = 11.46 \text{ kg}$$

$$T_1 = 390$$

$$T_2 = 770 \text{ K}$$

$$Q = m \cdot c_v \cdot \Delta T$$

$$= 11.46 \cdot 0.718 \cdot (770 - 390)$$

$$Q = 3126.74 \text{ kJ}$$

Use energy balance

4. 250 kJ of work goes into a closed system while the system loses 80 kJ of heat. If the initial internal energy of the system was 300 kJ, what is the final internal energy of the system?

$$\begin{array}{r} 300 \\ +250 \\ \hline 550 \\ -80 \\ \hline 470 \text{ kJ} \end{array}$$

$$E_{1,1} - E_{1,2} = E_{2,1} - E_{2,2}$$

$$E_2 = 250 - 80 + 300$$

$$E_2 = 470 \text{ kJ}$$

Show & sketch with energy input & output

5. A crane lifts a bucket of cement with a mass of 450 kg vertically up with a constant velocity of 2 m/s. Assuming $g=9.81$ m/s², the rate of power in kW used by the crane is

- a) 0.9
b) 4.42
c) 8.83

$$\dot{W} = (mg) \cdot v = 450 \cdot 9.81 \cdot 2 = 8829 \text{ W} = 8.83 \text{ kW}$$

7. If m is the mass and h is the specific enthalpy, then the total enthalpy of a system H is given by

- a) $H=h/m$
- b) $H=m/h$
- c) $H=mh$ ✓
- d) $H=h$
- e) None of the above is correct

8. A cylinder/piston contains 2 kg of air at 100 kPa, 20°C. The air is compressed polytropically to a pressure of 900 kPa. Calculate the absolute value of the work required if the polytropic exponent $n = 1.25$. Assume $R=0.287$ kJ/kg-K. (Hint: First calculate V_1 , and then V_2)

$m=2 \text{ kg}$ $P_1=100 \text{ kPa}$ $T_1=20^\circ\text{C}$
 $n=1.25$ $P_2=900 \text{ kPa}$
 $R=0.287$

~~$P_1 V_1^n = P_2 V_2^n$~~
 ~~$P_1 V_1 = n R T_1$~~
 ~~$V_1 = \frac{n R T_1}{P_1} = \frac{1.25 \cdot 0.287 \cdot 20 \cdot 1000}{100} = 1.05$~~
 ~~$P_1 V_1^n = P_2 V_2^n$~~
 ~~$V_2 = \sqrt[n]{\frac{P_1 V_1}{P_2}} = \sqrt[1.25]{\frac{100 \cdot 1.05}{900}} = 0.179$~~
 ~~$W = n R T \ln \left(\frac{V_2}{V_1} \right) = 1.25 \cdot 0.287 \cdot 20 \cdot 1000 \cdot \ln \left(\frac{0.179}{1.05} \right) = -12.69 \text{ kJ}$~~

Still wrong! Ideal Gas Law $PV = mRT$

9. kg of refrigerant R-134a passes through the throttle valve shown. The properties at the inlet are provided on the figure. The refrigerant loses an amount of heat, $Q=15$ kJ as it flows through the valve. By making an energy balance on the system, the computed value of the enthalpy at the exit state 2, h_2 in kJ is

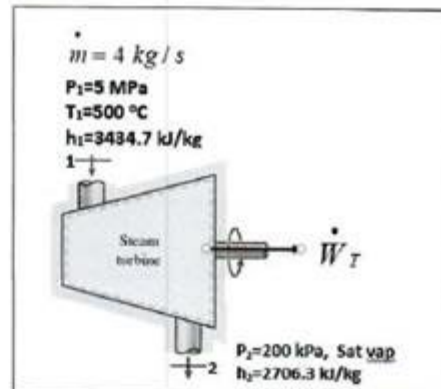
Do energy balance

$-W = m(h_2 - h_1)$ $W=0$
 $h_2 = \frac{Q}{m} - h_1$
 $= \frac{-15}{1} - 101.62$
 $h_2 = -116.62 \text{ kJ}$



10. By making an energy balance on the turbine shown in the figure, calculate the power output of the turbine in kW

$E_{in} = E_{out}$
 $\dot{m} h_1 = \dot{m} h_2 + \dot{W}_T$
 $\dot{W}_T = \dot{m} (h_1 - h_2)$
 $\dot{W}_T = 4 \cdot (3434.7 - 2706.3)$
 $\dot{W}_T = 2913.6 \text{ kJ/s}$



QUESTION 1 [25]

The 1.5 m^3 rigid tank shown below initially contains air at . The valve connected to the tank is opened allowing air at $P_i=500 \text{ kPa}$, $T_i=500\text{K}$ to enter the tank until the final condition in the tank is $T_2=400 \text{ K}$, $P_2=350 \text{ kPa}$ at which time the valve is completely closed. For air, assume the gas constant $R=0.287 \text{ kJ/kg}\cdot\text{K}$, Read all properties from the air tables.

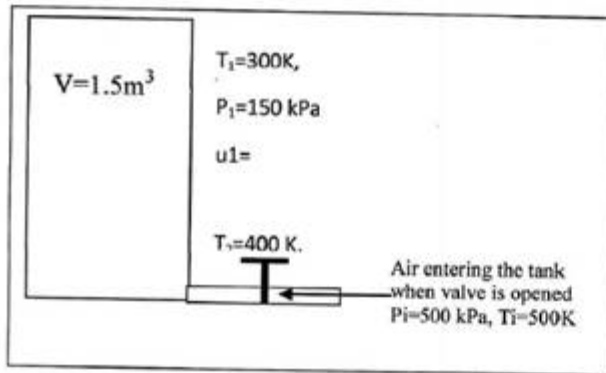


Figure 1

- i. Applying the ideal gas law, calculate the mass of air, m_1 , initially in the tank.

$$PV = mRT$$

$$m_1 = \frac{PV}{RT}$$

$$m_1 = \frac{150 \cdot 1.5}{0.287 \cdot 300} = 2.61 \text{ kg} \quad 4$$

- ii. Calculate the final mass of air, m_2 , in the tank.

$$m_2 = \frac{PV}{RT} = \frac{350 \cdot 1.5}{0.287 \cdot 400} = 4.53 \text{ kg} \quad 4$$

- iii. Applying the law of conservation of mass, calculate the total mass of air, m_i , that entered the tank during the process.

$$m_i = m_2 - m_1$$

$$= 4.57 - 2.613 = 1.96 \text{ kg}$$

$$m_i = 1.96 \text{ kg}$$

4

- iv. Determine the initial and final specific internal energy, u_1 and u_2 of the air in the tank, and the enthalpy h_i at the inlet to the tank/ from the air Tables

$$u_1 = 214.07 \text{ kJ/kg}$$

$$u_2 = 286.16 \text{ kJ/kg}$$

$$h_i = 503.02 \text{ kJ/kg}$$

- v. Determine the specific enthalpy, h_i , of the air entering the tank from the air Tables

$$h_i = 503.02 \text{ kJ/kg}$$

- vi. Making an energy Balance on the system, Calculate the total heat transfer during the process.

$$Q = m_i h_i - (m_2 u_2 - m_1 u_1) \quad \frac{1}{2} \text{ Make Energy Balance}$$

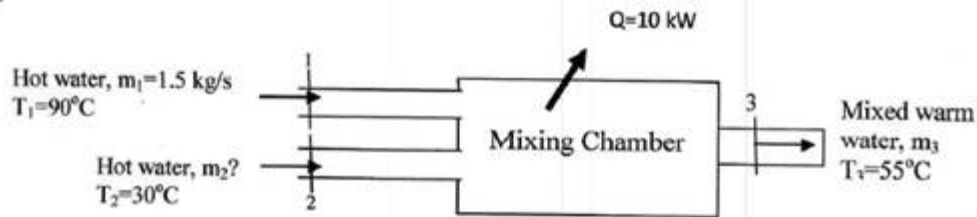
$$Q = 1.96 \cdot 503.02 - (4.573 \cdot 286.16 - 2.613 \cdot 214.07)$$

$$Q = 236.47 \text{ kJ}$$

QUESTION 2 [15]

A hot water stream at 90 °C enters a mixing chamber with a mass flow rate of 1.5 kg/s where it is mixed with a stream of cold water at 30 °C. After mixing, the mixed stream leaves the mixing chamber at 55 °C. Assume kinetic energy and potential energy changes are negligible. The system loses 10 kW of heat to the surroundings.

Figure 2



12.2
15

- i. Write the conservation of mass equation for the control volume and express the mass flow rate m_3 in terms of the mass flow rates m_1 and m_2

$$\dot{m}_{in} = \dot{m}_{out}$$

$$\dot{m}_1 + \dot{m}_2 = \dot{m}_3$$

✓ 2.2

- ii. Determine the specific enthalpies h_1 , h_2 , and h_3 at states 1, 2, and 3 respectively

$$h_1 = h_f(90^\circ\text{C}) = 376.82 \text{ kJ/kg}$$

1

$$h_2 = h_f(30^\circ\text{C}) = 125.79 \text{ kJ/kg}$$

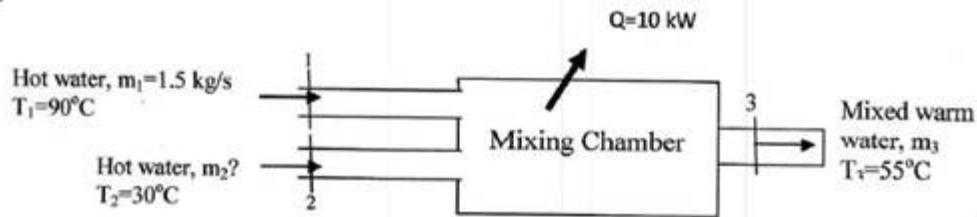
3

$$h_3 = h_f(55^\circ\text{C}) = 230.23 \text{ kJ/kg}$$

QUESTION 2 [15]

A hot water stream at 90°C enters a mixing chamber with a mass flow rate of 1.5 kg/s where it is mixed with a stream of cold water at 30°C . After mixing, the mixed stream leaves the mixing chamber at 55°C . Assume kinetic energy and potential energy changes are negligible. The system loses 10 kW of heat to the surroundings.

Figure 2



12.2
15

- i. Write the conservation of mass equation for the control volume and express the mass flow rate m_3 in terms of the mass flow rates m_1 and m_2

$$\dot{m}_{in} = \dot{m}_{out}$$

$$\dot{m}_1 + \dot{m}_2 = \dot{m}_3$$

✓ 2.2

- ii. Determine the specific enthalpies h_1 , h_2 , and h_3 at states 1, 2, and 3 respectively

$$h_1 = h_f(90^\circ\text{C}) = 376.82 \text{ kJ/kg}$$

1

$$h_2 = h_f(30^\circ\text{C}) = 125.79 \text{ kJ/kg}$$

3

$$h_3 = h_f(55^\circ\text{C}) = 230.23 \text{ kJ/kg}$$

iii. Applying energy balance on the control volume, determine the mass flow rate of the cold water, $\dot{m}_2$, in kg/s

$$\begin{aligned} E_{in} &= E_{out} \\ \dot{m}_1 h_1 + \dot{m}_2 h_2 &= \dot{m}_3 h_3 + Q_{out} \quad \checkmark \\ (1.5 \cdot 376.92) + (\dot{m}_2 \cdot 125.79) &= (1.5 + \dot{m}_2) \cdot 230.23 + 10 \\ \dot{m}_2 &= 2.01 \text{ kg/s} \quad \checkmark \end{aligned}$$

iv. How much heat is transferred across the mixing chamber boundary?

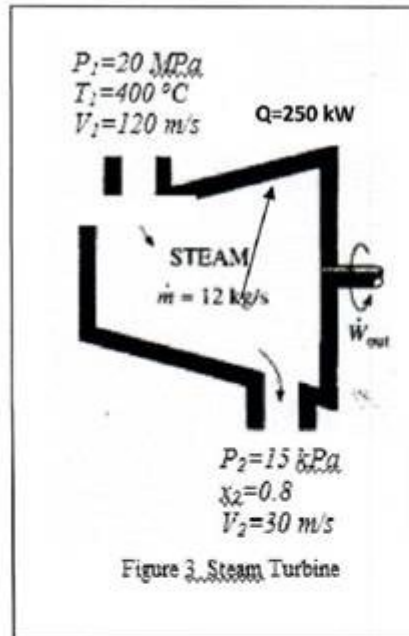
$$\begin{aligned} &h_1 + h_2 + h_3 + Q \\ &\dot{m}_1 h_1 + \dot{m}_2 h_2 + \dot{m}_3 h_3 + Q \\ &(1.5 \cdot 376.92) + (2.01 \cdot 125.79) + (3.5 \cdot 230.23) + 10 \\ &= 1634.0229 \text{ kW} \end{aligned}$$

Q is given!!
-1

QUESTION 3 [15]

Steam flows steadily through the turbine shown in Figure 3. The inlet conditions at state 1 and the outlet conditions at state 2 are shown in the Figure 1. Assume the kinetic and potential energy changes are zero.

The turbine loses 250 kW of heat to the surroundings.



Determine

- (i) the specific enthalpy at the inlet, h_1

$$T_1 = 400^\circ\text{C}$$

$$P_1 = 20 \text{ MPa}$$

$$h_1 = 2816.9 \text{ kJ/kg}$$

8/15

Figure

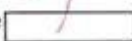


Figure 3

- ii) the specific enthalpy at the exit h_2

$$P_2 = 15 \text{ kPa} \quad x_2 = 0.8$$

$$h_2 = h_f + x h_{fg}$$

$$h_2 = 225.41 + 0.8(2201.2)$$

$$h_2 = 2026.13 \text{ kJ/kg}$$

AVERAGE

49+28.5=77.5 %

Score for this quiz: **49** out of 60

Submitted Nov 11 at 8:48am

This attempt took 40 minutes.

Question 1

3 / 3 pts

Air in a rigid closed vessel is initially at pressure $P_1=100$ kPa, $V_1=100$ oC. The air is heated to a final temperature $T_2=500$ oC. What the work done in kJ?

Correct!

0

Correct Answers

0 (with margin: 0)

Additional Comments:

Question 2

4 / 4 pts

Refrigerant R-134a at a temperature of 50°C has a specific volume, $v=0.12766$ m³/kg. The pressure in MPa is

Correct!

0.2

Correct Answers

0.2 (with margin: 0)

Question 3

4 / 7 pts

Air in a rigid closed vessel is initially at $P_1=100$ kPa, $T_1=390$ K, $V_1=12.5$ m³. The air is heated to a final temperature $T_2=770$ K. Assume the air is an ideal gas and that $R=0.287$ kJ/kg and $c_v=0.718$ kJ/kg-K. The total heat transferred in kJ is

You Answered

-4,457.2

Correct Answers

3,047 (with margin: 2)

Question 4

4 / 4 pts

250 kJ of work goes into a closed system while the system loses 80 kJ of heat. If the initial internal energy of the system was 300 kJ, what is the final internal energy of the system?

Correct!

470

Correct Answers

470 (with margin: 1)

Additional Comments:

Question 5

0 / 5 pts

A crane lifts a bucket of cement with a mass of 450 kg vertically up with a constant velocity of 2 m/s. Assuming $g=9.81 \text{ m/s}^2$, the rate of power in kW used by the crane. is

☐ 0.9☐ 4.42☐ 8.83☐ 8.52

Correct Answer

You Answered

☒ 1.8

Question 6

5 / 5 pts

As a result of heat transferred to a gas in a system, the temperature changed by 700 K.
What is this temperature change in $^{\circ}\text{R}$?

Correct!

1,260

Correct Answers

1,260 (with margin: 5)

Question 7

5 / 5 pts Regraded Score: 5 / 5 pts

⚠ This question has been regraded.

If m is the mass and h is the specific enthalpy, then the total enthalpy of a system H is given by

- ☐ $H=h/m$
- ☐ $H=m/h$
- ☒ $H=mh$
- ☐ $H=h$
- ☐ None of the above is correct

Correct!

Additional Comments:

Question 8

7 / 10 pts

A cylinder/piston contains 2 kg of air at 100 kPa, 20°C. The air is compressed polytropically to a pressure of 900 kPa. Calculate the absolute value of the work required if the polytropic exponent $n = 1.25$. Assume $R=0.287$ kJ/kg-K. (Hint: First calculate V_1 , and then V_2)

You Answered

2.744

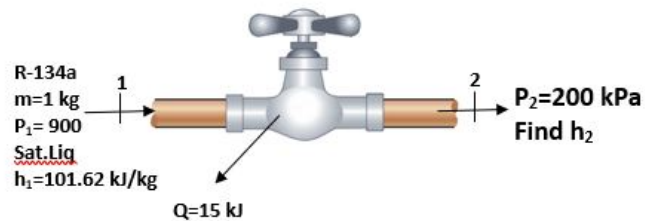
Correct Answers

5,385 (with margin: 50)

Question 9

7 / 7 pts

1 kg of refrigerant R-134a passes through the throttle valve shown. The properties at the inlet are provided on the figure. The refrigerant loses an amount of heat, $Q=15$ kJ as it flows through the valve. By making an energy balance on the system, the computed value of the enthalpy at the exit state 2, h_2 in kJ is



Correct!

86.62

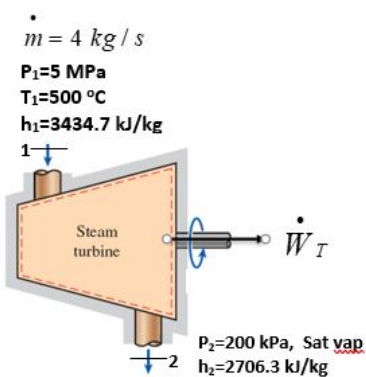
Correct Answers

86.62 (with margin: 5)

Question 10

10 / 10 pts

By making an energy balance on the turbine shown in the figure, calculate the power output of the turbine in kW.



Correct!

2,913.6

Correct Answers

2,913.6 (with margin: 50)

THERMODYNAMICS I FALL 2021 SEMESTER TEST 2 Part B

ANSWER QUESTION 1 AND ANY 1 OTHER QUESTION

SHOW YOUR CALCULATIONS

11/11/2021

Name of Student (PRINT) Tyson Morris

I UNDERSTAND THAT CHEATING OR SEEKING HELP DURING THIS QUIZ WILL RESULT IN "F" GRADE: _____

Student's Signature

QUESTION 1 [25]

The 1.5 m³ rigid tank shown below initially contains air at . The valve connected to the tank is opened allowing air at P_i=500 kPa, T_i=500K to enter the tank until the final condition in the tank is T₂=400 K, P₂=350 kPa at which time the valve is completely closed. For air, assume the gas constant R=0.287 kJ/kg-K, Read all properties from the air tables.

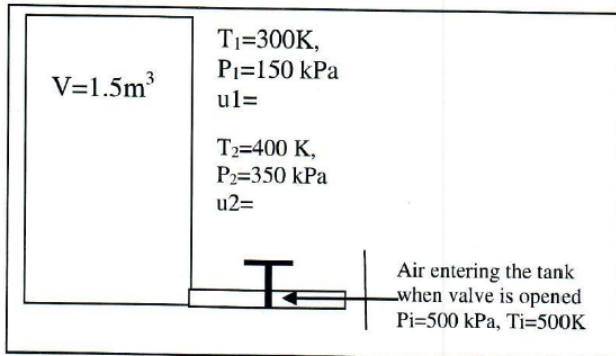


Figure 1

- i. Applying the ideal gas law, calculate the mass of air, m₁, initially in the tank.

$$P_1 V_1 = m_1 R T_1$$

$$(150)(1.5) = m_1 (0.287)(300)$$

$$5.23 = m_1$$

Do the algebra first
Units
How?

$$m_1 = \frac{P_1 V_1}{R T_1}$$

- ii. Calculate the final mass of air, m₂, in the tank.

$$P_2 V_2 = m_2 R T_2$$

$$(350)(1.5) = m_2 (0.287)(400)$$

$$4.57 = m_2$$

Do the algebra
Units

$$m_2 = \frac{P_2 V_2}{R T_2}$$

20 1/2
25

28 1/2
40

- iii. Applying the law of conservation of mass, calculate the total mass of air, m_i , that entered the tank during the process.

$$m_i = m_2 - m_1$$

$$m_i = 4.57 - 5.23$$

$$m_i = -0.66$$

- iv. Determine the initial and final specific internal energy, u_1 and u_2 of the air in the tank, and the enthalpy h_i at the inlet to the tank./ from the air Tables

$$u_1 @ 300K = 214.07 \text{ kJ/kg}$$

$$u_2 @ 400K = 280.16 \text{ kJ/kg}$$

$$h_i @ 300K = 503.02 \text{ kJ/kg}$$

- v. Determine the specific enthalpy, h_i , of the air entering the tank from the air Tables

$$503.02 \text{ kJ/kg}$$

- vi. Making an energy Balance on the system, Calculate the total heat transfer during the process.

$$E_2 = E_1 + E_i$$

final initial in

$$Q - W = \sum_{out} m h - \sum_{in} m h + (m_2 u_2 - m_1 u_1)$$

$$Q = \sum_{in} m h + (m_2 u_2 - m_1 u_1)$$

$$Q = 5.226(503.02) + (4.57)(280.16) - (5.23)(214.07)$$

$$Q = 2628.78 + 1285.1651$$

$$3913.95 \text{ kJ}$$

$$P_i V = m R T_i$$

$$(500)(1.5) = m(0.287)(500)$$

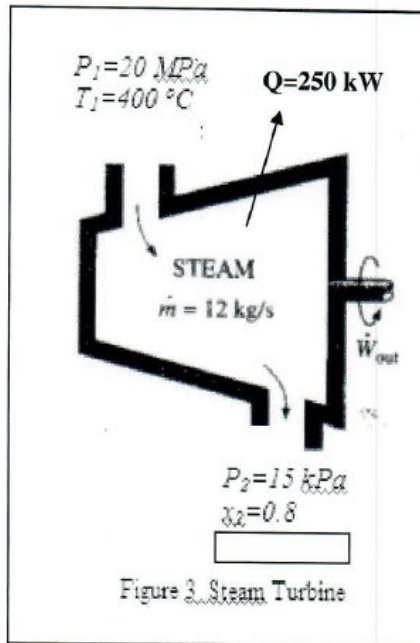
$$750 = m(143.5)$$

$$m = 5.226$$

Apply $E_{in} - E_{out} = E_2 - E_1$
to system

QUESTION 3 [15]

Steam flows steadily through the turbine shown in Figure 3. The inlet conditions at state 1 and the outlet conditions at state 2 are shown in the Figure 1. Assume the kinetic and potential energy changes are zero. The turbine loses 250 kW of heat to the surroundings.



Determine

- (i) the specific enthalpy at the inlet, h_1

suggested
steam table
@ 20 MPa
400°C

$$= 2816.9 \text{ kJ/kg}$$

8/15

2

- ii) the specific enthalpy at the exit h_2

@ 15 kPa, $h_f = 225.94$ $h_{fg} = 2372.3$

$x = 0.8$

$$h_2 = h_f + x h_{fg}$$

$$h_2 = 225.94 + (0.8)(2372.3)$$

$$h_2 = 2123.78 \text{ kJ/kg}$$

- (i) By making an energy balance on the turbine, calculate the power output of the turbine in kW.

$$W = \dot{Q} + \dot{m} (h_1 - h_2)$$

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

$$\dot{W} = (12)(2816.9 - 2123.78)$$

$$\dot{W} = 8317.44 \text{ kW}$$

Apply the 1st law

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{m} h_1 = \dot{m} h_2 + \dot{W} + \dot{Q}$$

to solve for $\dot{W}$

BELOW AVERAGE

26+15.5=41.5 %

Score for this quiz: **26** out of 60

Submitted Nov 11 at 8:50am

This attempt took 41 minutes.

Question 1

3 / 3 pts

Air in a rigid closed vessel is initially at pressure $P_1=100$ kPa, $V_1=100$ oC. The air is heated to a final temperature $T_2=500$ oC. What the work done in kJ?

Correct!

0

Correct Answers

0 (with margin: 0)

Additional Comments:

Question 2

4 / 4 pts

Refrigerant R-134a at a temperature of 50°C has a specific volume, $v=0.12766$ m³/kg. The pressure in MPa is

Correct!

0.2

Correct Answers

0.2 (with margin: 0)

Question 3

5 / 7 pts

Air in a rigid closed vessel is initially at $P_1=100$ kPa, $T_1=390$ K, $V_1=12.5$ m³. The air is heated to a final temperature $T_2=770$ K. Assume the air is an ideal gas and that $R=0.287$ kJ/kg and $c_v=0.718$ kJ/kg-K. The total heat transferred in kJ is

You Answered

272.84

Correct Answers

3,047 (with margin: 2)

Question 4

4 / 4 pts

250 kJ of work goes into a closed system while the system loses 80 kJ of heat. If the initial internal energy of the system was 300 kJ, what is the final internal energy of the system?

Correct!

470

Correct Answers

470 (with margin: 1)

Additional Comments:

Question 5

5 / 5 pts

A crane lifts a bucket of cement with a mass of 450 kg vertically up with a constant velocity of 2 m/s. Assuming $g=9.81 \text{ m/s}^2$, the rate of power in kW used by the crane. is

☐ 0.9☐ 4.42

Correct!

☒ 8.83☐ 8.52☐ 1.8

Unanswered

Question 6

0 / 5 pts

As a result of heat transferred to a gas in a system, the temperature changed by 700 K.
What is this temperature change in $^{\circ}\text{R}$?

You Answered

Correct Answers

1,260 (with margin: 5)

Question 7

5

/ 5 pts Regraded Score: 5 / 5 pts

 This question has been regraded.

If m is the mass and h is the specific enthalpy, then the total enthalpy of a system H is given by

- ☐ $H=h/m$
- ☐ $H=m/h$
- ☒ $H=mh$
- ☐ $H=h$
- ☐ None of the above is correct

Correct!

Additional Comments:

Unanswered

Question 8

0

/ 10 pts

A cylinder/piston contains 2 kg of air at 100 kPa, 20°C. The air is compressed polytropically to a pressure of 900 kPa. Calculate the absolute value of the work required if the polytropic exponent $n = 1.25$. Assume $R=0.287$ kJ/kg-K. (Hint: First calculate V_1 , and then V_2)

You Answered

Correct Answers

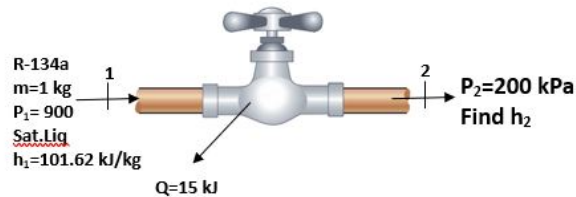
5,385 (with margin: 50)

Unanswered

Question 9

0 / 7 pts

1 kg of refrigerant R-134a passes through the throttle valve shown. The properties at the inlet are provided on the figure. The refrigerant loses an amount of heat, $Q=15$ kJ as it flows through the valve. By making an energy balance on the system, the computed value of the enthalpy at the exit state 2, h_2 in kJ is



You Answered

Correct Answers

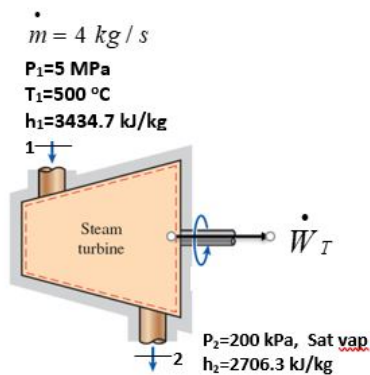
86.62 (with margin: 5)

Unanswered

Question 10

0 / 10 pts

By making an energy balance on the turbine shown in the figure, calculate the power output of the turbine in kW.



You Answered

Correct Answers

2,913.6 (with margin: 50)

THERMODYNAMICS I FALL 2021 SEMESTER TEST 2 Part B

ANSWER QUESTION 1 AND ANY 1 OTHER QUESTION

SHOW YOUR CALCULATIONS

11/11/2021

Name of Student (PRINT) Tyler Rhodes

I UNDERSTAND THAT CHEATING OR SEEKING HELP DURING THIS QUIZ WILL RESULT IN "F" GRADE: Tyler Rhodes

Student's Signature

QUESTION 1 [25]

The 1.5 m³ rigid tank shown below initially contains air at . The valve connected to the tank is opened allowing air at P_i=500 kPa, T_i=500K to enter the tank until the final condition in the tank is T₂=400 K, P₂=350 kPa at which time the valve is completely closed. For air, assume the gas constant R=0.287 kJ/kg-K, Read all properties from the air tables.

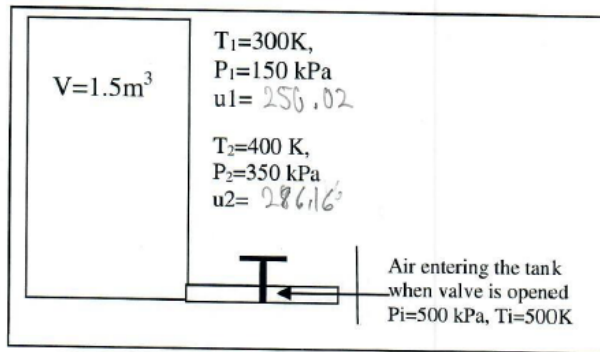


Figure 1

- i. Applying the ideal gas law, calculate the mass of air, m₁, initially in the tank.

$m_1 = 2.613 \text{ kg}$

$$P_1 V_1 = m_1 R T_1$$

$$m_1 = \frac{P_1 V_1}{R T_1} \rightarrow m_1 = \frac{(150 \text{ kPa})(1.5 \text{ m}^3)}{(0.287 \text{ kJ/kg-K})(300 \text{ K})}$$

- ii. Calculate the final mass of air, m₂, in the tank.

$m_2 = 4.573 \text{ kg}$

$$m_2 = \frac{P_2 V_2}{R T_2} = \frac{(350 \text{ kPa})(1.5 \text{ m}^3)}{(0.287 \text{ kJ/kg-K})(400 \text{ K})}$$

- iii. Applying the law of conservation of mass, calculate the total mass of air, m_i , that entered the tank during the process.

Apply $m_i - m_e = m_2 - m_1$ $m_i = \frac{p_i V_0}{R T_i} = \frac{(500 \text{ kPa})(9.8 \text{ m}^3)}{(0.287 \frac{\text{kJ}}{\text{kg} \cdot \text{K}})(500 \text{ K})}$

~~$m_i = 5.226 \text{ kg}$~~ 0

- iv. Determine the initial and final specific internal energy, u_1 and u_2 of the air in the tank, and the enthalpy h_i at the inlet to the tank./ from the air Tables

~~$u_1 = 250.12 \text{ kJ/kg}$~~

$u_2 = 286.16 \text{ kJ/kg}$

$h_i = 503.02$

- v. Determine the specific enthalpy, h_i , of the air entering the tank from the air Tables

~~$h_i = 503.02$~~

- vi. Making an energy Balance on the system. Calculate the total heat transfer during the process.

Need to learn how to apply to systems!
mass & energy balance

$E_{in} - E_{out} = E_2 - E_1$

$Q - W = m_i(h_i + \frac{V_i^2}{2} + g z_i) - m_e(h_e + \frac{V_e^2}{2} + g z_e)$

$Q = m_i(h_i)$

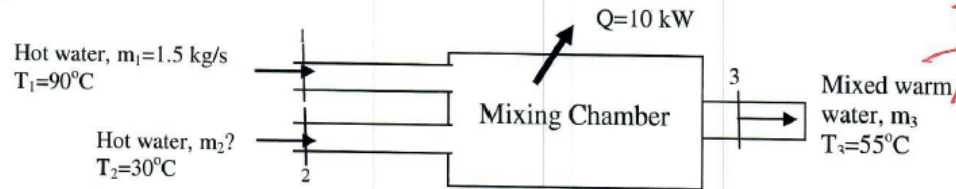
$Q = (5.226 \text{ kg})(503.02 \frac{\text{kJ}}{\text{kg}})$

~~$Q = 2629.024 \text{ kJ}$~~

QUESTION 2 [15]

A hot water stream at 90°C enters a mixing chamber with a mass flow rate of 1.5 kg/s where it is mixed with a stream of cold water at 30°C . After mixing, the mixed stream leaves the mixing chamber at 55°C . Assume kinetic energy and potential energy changes are negligible. The system loses 10 kW of heat. To the surroundings.

Figure 2



- i. Write the conservation of mass equation for the control volume and express the mass flow rate m_3 in terms of the mass flow rates m_1 and m_2

$$m_1 + m_2 = m_3$$

$$Q - W = m_3 h_3 - m_1 h_1 - m_2 h_2$$

$$Q - 0 = m_3 h_3 - m_1 h_1 - m_2 h_2$$

$$Q = (m_3 h_3) - (m_1 h_1 + m_2 h_2)$$

- ii. Determine the specific enthalpies h_1 , h_2 , and h_3 at states 1, 2, and 3 respectively

$$m_1 h_1 = m_3 h_3$$

$$m_2 h_2 = m_3 h_3 - m_1 h_1$$

$$m_2 h_2 = m_3 h_3 - m_1 h_1$$

- iii. Applying energy balance on the control volume, determine the mass flow rate of the cold water, m_2 , in kg/s

$$Q = 0 - (m_2 h_2 + m_1 h_1)$$

$$Q + m_1 h_1 = -m_2 h_2$$

$$-Q - m_1 h_1 = m_2 h_2$$

$$E_{in} = E_{out} + Q$$

$$m_1 h_1 + m_2 h_2 = m_3 h_3 + Q$$

$$= (m_1 + m_2) h_3$$

THERMODYNAMICS I
FALL 2021

Title of Assignment: TEST 3

TOPICS COVERED IN TEST 3

Test 3 covered the following topics:

1. The application of the First Law in the form of the steady state steady flow equation to the vapor power cycle
2. The refrigeration & Heat pump cycles
3. Gas mixtures

THERMODYNAMICS I
FALL 2021

SAMPLE TEST QUESTIONS, SOLUTION,
AND GRADING SCHEME FOR TEST 3

Test 3 Questions, Solution & Grading Scheme

THERMODYNAMICS I FALL 2021 FINAL EXAM PART B ANSWER QUESTION 1 and any other 1 QUESTION

Show your work clearly and answer the sub-questions in the order asked.

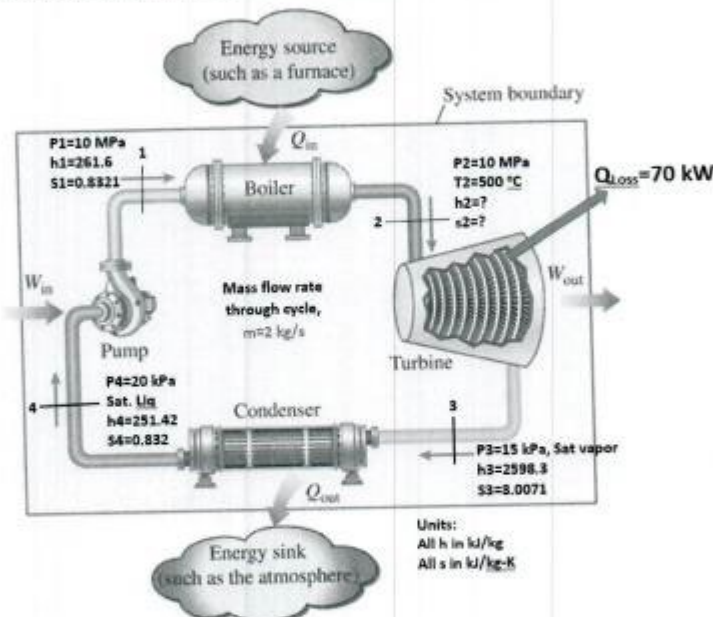
Name Muster Solution

12/07/2021

By writing my name above, I understand and agree that any dishonesty on this exam will result in an "F" grade in the course.

QUESTION 1 [25 Points]

For the steam power cycle shown in the Figure, the mass flow rate of water through the cycle is 2 kg/s. All of the properties at the various state points are indicated in the Figure.



- Find the specific enthalpy h_2 and the specific entropy, s_2 at state 2 from your steam Tables. *Double check your answers to ensure you have read the table correctly.*
- By making an energy balance on the boiler, calculate the rate of heat input to the boiler, Q_{in} in kW
- By making an energy balance on the turbine, calculate the power output of the turbine W_{out} , in kW
- By making an energy balance on the condenser, calculate the rate of heat rejected from the condenser, Q_{out} in kW
- By making an energy balance on the pump, calculate the power input to the pump, W_{in} , in kW
- calculate the net power output, W_{net} , in kW
- Calculate the thermal efficiency of the cycle
- Determine S_{gen} for the Turbine in kW/K and indicate if the turbine process is possible or impossible, reversible or irreversible. Assume the turbine is losing heat to the surroundings at $T_o = 300$ K
- Determine S_{gen} for the condenser in kW/K if the heat is lost to the surroundings at $T_o = 300$ K and indicate if the condenser process is possible or impossible, reversible or irreversible.

a) At $P_2 = 10 \text{ MPa}$, $T_2 = 500^\circ\text{C}$ we have superheated vapor

$$h_2 = 3375.1 \text{ kJ/kg}, \quad s_2 = 6.5995 \text{ kJ/kg-K}$$

(b) $E_{in} = E_{out}$

$$mh_1 + \dot{Q}_{in} = mh_2$$

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

$$\dot{Q}_{in} = (2 \text{ kg/s})(3375.1 - 261.6) \frac{\text{kJ}}{\text{kg}} = 6227.0 \text{ kW}$$

(c) $E_{in} = E_{out}$

$$mh_2 = \dot{Q}_{loss} + W_{out} + mh_3$$

$$W_{out} = m(h_2 - h_3) - \dot{Q}_{loss}$$

$$= (2 \text{ kg/s})(3375.1 - 2598.3) \frac{\text{kJ}}{\text{kg}} = 1483.6 \text{ kW}$$

(d) $E_{in} = E_{out}$

$$mh_3 = mh_4 + \dot{Q}_{out}$$

$$\dot{Q}_{out} = m(h_3 - h_4) = (2 \text{ kg/s})(2598.3 - 251.42) \frac{\text{kJ}}{\text{kg}} = 4693.8 \text{ kW}$$

(e) $E_{in} = E_{out}$

$$mh_4 + W_{in} = mh_1$$

$$W_{in} = m(h_1 - h_4) = (2 \text{ kg/s})(261.6 - 251.42) \frac{\text{kJ}}{\text{kg}} = 20.63 \text{ kW}$$

(f) $W_{net} = W_{out} - W_{in}$

$$= (1483.6 - 20.63) \text{ kW} = 1463.2 \text{ kW}$$

(g) $\eta_{th} = \frac{W_{net}}{\dot{Q}_{in}}$

$$= \frac{1463.2 \text{ kW}}{6227.0 \text{ kW}} = 0.235 \quad (23.5\%)$$

(h) For Turbine

$$S_{gen} = \Delta S_{sys} + \Delta S_{surr}$$

$$= 0 + m s_3 - m s_2 + \frac{\dot{Q}_{loss}}{T_0}$$

$$= (2 \text{ kg/s})(8.0071 - 6.5995) \frac{\text{kJ}}{\text{kg-K}} + \frac{70 \text{ kW}}{300 \text{ K}}$$

$$S_{gen} = 3.049 \text{ kW/K}$$

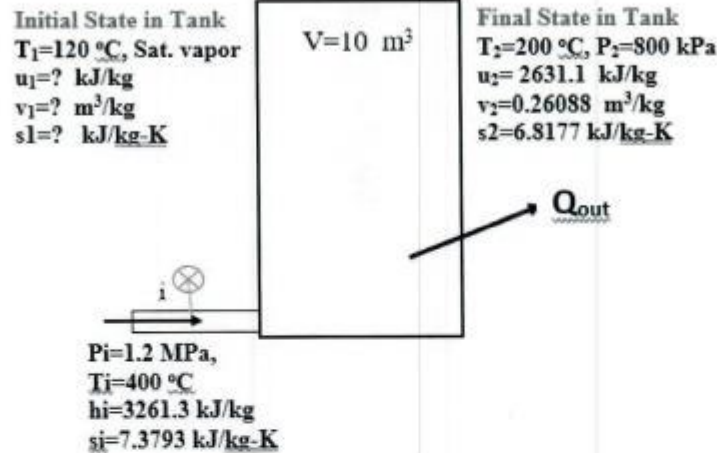
$S_{gen} > 0 \Rightarrow$ process is possible but irreversible

(i) For Condenser, $S_{gen} = \Delta S_{sys} + \Delta S_{surr} = m s_4 - m s_3 + \frac{\dot{Q}_{out}}{T_0} = (2 \text{ kg/s})(-0.832 - 8.007) + \frac{4693.8}{300}$

Bonus
Questions

QUESTION 2 [25 Points]

A rigid tank of volume 10 m^3 initially contains saturated water vapor at a temperature of 120°C . Steam at a pressure 1.2 MPa and a temperature of 400°C enters the tank through a valve in steam line that is connected to the tank until the final pressure in the tank is 800 kPa , at which time the temperature is 200°C . All kinetic and potential energy effects can be neglected. A schematic of the problem and properties at all state points except state 1 are shown in the figure below.



- Given that the initial state of the steam is a saturated vapor at $T_1=120^\circ\text{C}$, read the values of the specific volume, v_1 , specific internal energy, u_1 , and the specific entropy, s_1 at state 1
- Calculate the initial mass, m_1 , of steam in the tank in kg
- Calculate the final mass, m_2 , of steam in the tank in kg
- By making a mass balance on the control volume, calculate the mass of steam that entered the tank, m_i , in kg
- By making an energy balance on the system and assuming the system lost heat as shown on the diagram, compute the heat lost Q_{out} during the process in kJ
- Calculate the entropy change of the system, ΔS_{system} in kJ/K
- Calculate the entropy change of the surrounding, ΔS_{sur} in kJ/K, if the heat is lost to the surrounding at $T_b=300 \text{ K}$
- Calculate the entropy generated, S_{gen} in kJ/K
- From your answer for S_{gen} , explain whether the process as described is possible or impossible, reversible or irreversible,

(a) At $T_1 = 120^\circ\text{C}$, Saturated Vapor
 $S_1 = S_g = 7.1292 \text{ kJ/kg-K}$ $V_1 = 0.89133 \text{ m}^3/\text{kg}$
 $u_1 = u_g = 2528.9 \text{ kJ/kg-K}$ } 3

(b) $m_1 = \frac{V}{V_1} = \frac{10 \text{ m}^3}{0.89133 \text{ m}^3/\text{kg}} = 11.22 \text{ kg}$ } 3

(c) $m_2 = \frac{V}{V_2} = \frac{10 \text{ m}^3}{0.26088 \text{ m}^3/\text{kg}} = 38.33 \text{ kg}$ } 3

(d) $m_i - m_e = m_2 - m_1$ $m_e = 0$
 $m_i = m_2 - m_1 = (38.33 - 11.22) \text{ kg} = 27.11 \text{ kg}$ } 3

(e) $E_{in} - E_{out} = E_2 - E_1$
 $m_i h_i - Q_{out} = m_2 u_2 - m_1 u_1$
 $Q_{out} = m_i h_i - (m_2 u_2 - m_1 u_1)$
 $= (27.11 \text{ kg})(3261.3 \text{ kJ/kg}) - [(38.33)(2631.1) - (11.22)(2528.9)] \text{ kJ}$
 $= 15,939.8 \text{ kJ}$ } 3

(f) $\Delta S_{\text{system}} = m_2 s_2 - m_1 s_1$
 $= (38.33 \text{ kg})(6.8177 \frac{\text{kJ}}{\text{kg-K}}) - (11.22 \text{ kg})(7.1292 \frac{\text{kJ}}{\text{kg-K}})$
 $= 181.4 \frac{\text{kJ}}{\text{K}}$ } 1/2

(g) $\Delta S_{\text{surr}} = -m_i s_i + \frac{Q_{out}}{T_0}$
 $= -(27.11 \text{ kg})(7.3793 \frac{\text{kJ}}{\text{kg-K}}) + \frac{15,939.8}{300}$
 $= -146.9 \frac{\text{kJ}}{\text{K}}$ } 1/2

(h) $S_{\text{gen}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}}$
 $= (181.4 - 146.9) \frac{\text{kJ}}{\text{K}}$
 $= 34.5 \frac{\text{kJ}}{\text{K}}$ } 1/2

(i) $S_{\text{gen}} > 0$ Thus process as described is possible but irreversible } 1/2

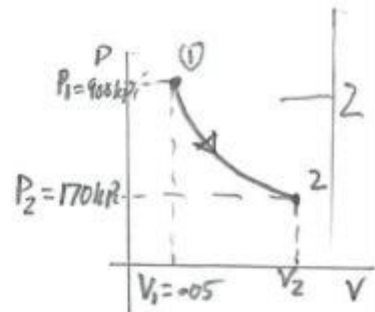
QUESTION 3 [25 Points]

Air contained in a piston cylinder arrangement is expanded in a polytropic process from $P_1=900\text{ kPa}$, $V_1=0.05\text{ m}^3$, $T_1=400\text{ }^\circ\text{C}$ to $P_2=170\text{ kPa}$. The polytropic index, $n=1.2$. Assume that the air is an ideal gas with constant specific heats and that $R=0.287\text{ kJ/kg}\cdot\text{K}$, $c_p=1.005\text{ kJ/kg}\cdot\text{K}$ and $c_v=0.718\text{ kJ/kg}\cdot\text{K}$.

- Show the process on a $P=V$ diagram
- Calculate the final total volume V_2 , in m^3 .
- Calculate the work done, W in kJ and indicate the direction of the work as input or output. Make a sketch of the system and indicate the direction of the work
- Calculate the mass of air in the system in kg .
- Calculate the final temperature, T_2 , in K
- Applying energy balance to the system, calculate the heat transfer, Q in kJ and indicate whether it is heat input or output. Show the direction of the heat input or output on a sketch of the system.
- Calculate the entropy change of the system in kJ/K
- Calculate the entropy change of the surroundings if the surrounding is at $T_o=300\text{ K}$
- Calculate S_{gen} and from the value of S_{gen} , indicate whether the process is possible or impossible, reversible or irreversible.

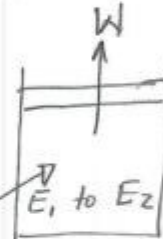
(a) Polytropic expansion process

$$\begin{aligned}
 (b) \quad P_2 V_2^{1.2} &= P_1 V_1^{1.2} \\
 V_2^{1.2} &= V_1^{1.2} \left(\frac{P_1}{P_2} \right) \\
 V_2 &= V_1 \left(\frac{P_1}{P_2} \right)^{\frac{1}{1.2}} = 0.05 \text{ m}^3 \left(\frac{900}{170} \right)^{\frac{1}{1.2}} \\
 V_2 &= 0.2005 \text{ m}^3
 \end{aligned}$$



$$\begin{aligned}
 (c) \quad W &= \frac{P_2 V_2 - P_1 V_1}{1 - n} \\
 &= \frac{(170 \text{ kPa})(0.2005 \text{ m}^3) - (900 \text{ kPa})(0.05 \text{ m}^3)}{1 - 1.2}
 \end{aligned}$$

$$W = 54.57 \text{ kJ}$$



$$\begin{aligned}
 (d) \quad P_1 V_1 &= m R \bar{T}_1 \quad \bar{T}_1 = 400 + 273.15 = 673.15 \text{ K} \\
 m &= \frac{P_1 V_1}{R \bar{T}_1} = \frac{(900 \text{ kPa})(0.05 \text{ m}^3)}{(0.287 \frac{\text{kJ}}{\text{kg} \cdot \text{K}})(673.15 \text{ K})}
 \end{aligned}$$

$$m = 0.2329 \text{ kg}$$

$$\begin{aligned}
 (e) \quad P_2 V_2 &= m R \bar{T}_2 \Rightarrow \bar{T}_2 = \frac{P_2 V_2}{m R} \\
 \bar{T}_2 &= \frac{(170 \text{ kPa})(0.2005 \text{ m}^3)}{(0.287 \frac{\text{kJ}}{\text{kg} \cdot \text{K}})(0.2329)} = 509.9 \text{ K}
 \end{aligned}$$

$$\begin{aligned}
 (f) \quad E_{in} - E_{out} &= E_2 - E_1 \\
 Q - W &= m(u_2 - u_1) \\
 Q &= W + m(u_2 - u_1) \\
 &= 54.57 \text{ kJ} + (0.2329 \text{ kg})(0.718 \frac{\text{kJ}}{\text{kg} \cdot \text{K}})(509.9 - 673.15) \text{ K} \\
 &= 27.27 \text{ kJ}
 \end{aligned}$$

$$\begin{aligned}
 (g) \quad \Delta S_{\text{system}} &= m(s_2 - s_1) = m \left[c_p \ln \left(\frac{T_2}{T_1} \right) - R \ln \left(\frac{P_2}{P_1} \right) \right] \\
 &= (0.2329) \left[1.005 \ln \left(\frac{509.9}{673.15} \right) - 0.287 \ln \left(\frac{170}{900} \right) \right] = 0.0464 \frac{\text{kJ}}{\text{K}}
 \end{aligned}$$

$$(h) \quad \Delta S_{\text{sur}} = -\frac{Q}{T} = -\frac{27.27}{300} = -0.09088 \frac{\text{kJ}}{\text{K}}$$

ABOVE AVERAGE

FALL 2021 FINAL EXAM PART A Results for Safiatou Zampaligre

Score for this quiz: 40 out of 50

Submitted Dec 7 at 6pm

This attempt took 54 minutes.

40+34=74 %

Question 1

4 / 4 pts

A fan accelerates air from a velocity of 0 m/s to a velocity of 15 m/s at a volume flow rate of 5 m³/s. If the density of the air is 1.2 kg/m³, the minimum power needed for the fan in Watts is

Correct!

675

Correct Answers

675 (with margin: 10)

Additional Comments:

Question 2

3 / 3 pts

A 7.5 m³ rigid vessel contains water at 10 MPa, and 400 °C. The mass of water in the vessel in kg is

Correct!

283.7

Correct Answers

283.7 (with margin: 1)

Question 3

3 / 3 pts

During a heating process, the temperature of an object rises by 250 °C.
This temperature rise in °F is

Correct!

450

Correct Answers

450 (with margin: 5)

Additional Comments:

Question 4

0 / 4 pts

Helium is in a 5.0 ft³ container at a temperature of 12.35 °R and pressure of 66.4 psia. For helium, the critical pressure, $P_c=33.2$ psia, and the critical temperature, $T_c=9.5$ °R. Calculate the reduced temperature and reduced pressure and use these to determine the value of Z from the compressibility chart. The value of Z read from the chart is approximately (Note: the compressibility chart is in chapter 3, page 137 and in Figure A-15 on page 906 of the textbook).

Write down your answer for Z for use in the next question.

☐ 0.30

Correct Answer

☐ 0.7☐ 0.8

You Answered

☒ 1.0

Question 5

3 / 3 pts

Helium is in a 5.0 ft^3 container at a temperature of 12.35°R and pressure of 66.4 psia . For helium, the critical pressure, $P_c=33.2 \text{ psia}$, and the critical temperature,

$T_c=9.5^\circ\text{R}$. Using the compressibility factor Z you obtained in the previous question, if for helium $R=0.4961 \text{ Btu/lbm-}^\circ\text{R}$, the computed mass of the helium in the tank in lbm is

☐ 54.2☐ 67.7

Correct!

☒ 77.41☐ 120.4☐ 180.6

Question 6

3 / 3 pts

If P is the pressure, v is the specific volume, T is the temperature, R is the specific gas constant and Z is the compressibility factor, which of the following statements represents the ideal gas law

☐ $Pv=ZRT$ as long as $Z>0$

Correct!

☒ $Pv=ZRT$ if $Z=1$ ☐ $Pv=ZRT$ if Z is any number☐ $Pv=ZRT$ if $Z>1$ ☐ $Pv=ZRT$ if $Z<1$

Question 7

3 / 3 pts

An engineer claims he has designed an engine that takes in 7500kJ of heat from a reservoir at 400 °C and rejects heat to a reservoir at 27 °C with a net work output of 3000 kJ. The % efficiency of this engine is

Write down computed efficiency of the engine for use in question 9

Correct!

60

Correct Answers

60 (with margin: 2)

Additional Comments:

Question 8

0 / 3 pts

An engineer claims he has designed an engine that takes in 7500kJ of heat from a reservoir at 400 °C and rejects heat to a reservoir at 27 °C with a net work output of 3000 kJ. The % efficiency of a Carnot engine operating between the two given temperatures is

Write down computed efficiency of the Carnot engine for use in question 9

You Answered

93.25

Correct Answers

55 (with margin: 2)

Question 9

0 / 3 pts

An engineer claims he has designed an engine that takes in 7500 kJ of heat from a reservoir at 400 °C and rejects heat to a reservoir at 27 °C with a net work output of 3000 kJ. From your answers for the efficiency of the engine in question 7 and that of the Carnot engine operating between the same two temperatures in question 8, which of the statements is true about his claim.

- ☐ the engine is possible but reversible
- ☐ the engine is impossible
- ☐ the engine is impossible but reversible
- ☒ the engine is possible but irreversible
- ☐ (E) none of the above

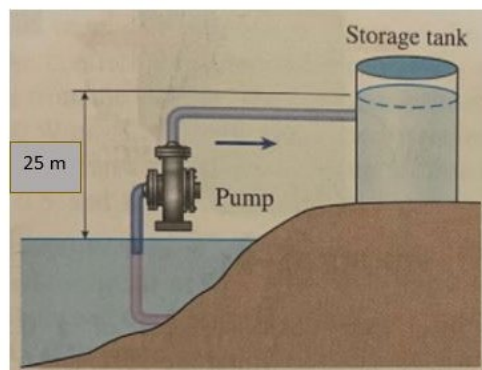
Correct Answer

You Answered

Question 10

4 / 4 pts

Water of density 1000 kg/m³ is pumped from a lake to a storage tank as shown in the Figure at a location where $g=9.81 \text{ m/s}^2$. The volume flow rate of the water is 0.1 m³/s and the electrical power input to motor driving the pump is 27 kW. The overall efficiency of the pump-motor unit in % is



Correct!

90.83

Correct Answers

90.8 (with margin: 5)

Question 11

4 / 4 pts

2.5 kg of helium is in a piston cylinder arrangement with an initial volume, $V_1=3.5 \text{ m}^3$. The helium is compressed to a final volume of 1 m^3 while its **pressure is maintained constant at 250 kPa**.

The absolute value of the work done during this constant pressure process in kJ is

Correct!

☒ 625☐ 150☐ -525☐ 525☐ -375

Additional Comments:

Question 12

3 / 3 pts

A closed rigid tank contains air at $P_1=700 \text{ kPa}$ and $T_1=300 \text{ }^\circ\text{C}$. As a result of heat transfer to the surroundings, the temperature inside the tank drop to $100 \text{ }^\circ\text{C}$. The work done during the process in kJ is

Correct!

Correct Answers

0 (with margin: 1)

Question 13

4 / 4 pts

A piston cylinder device initially contains 0.5 m^3 of air at $P_1=900 \text{ kPa}$, $T_1=200^\circ\text{C}$. The air is **isothermally** expanded to a final volume, $V_2=1.5 \text{ m}^3$. The work done during the process in kJ is

Correct!

494.375

Correct Answers

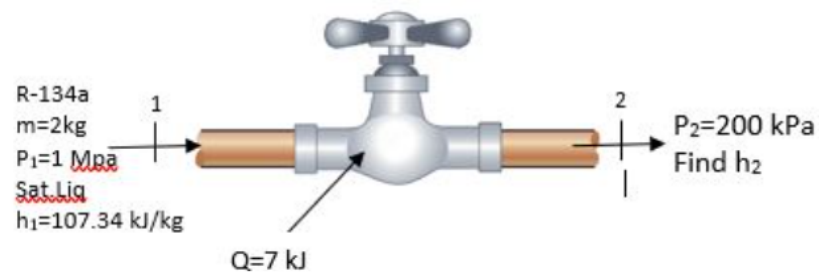
494.4 (with margin: 10)

Additional Comments:

Question 14

3 / 3 pts

2 kg of refrigerant R-134a passes through the throttle valve shown. The properties at the inlet are provided on the figure. The refrigerant gains an amount of heat, $Q=7 \text{ kJ}$ as it flows through the valve.



By making an energy balance on the system, the computed value of the enthalpy at the exit state 2, h_2 in kJ/kg is

Correct!

110.84

Correct Answers

110.8 (with margin: 2)

THERMODYNAMICS I
FALL 2021 FINAL EXAM PART B
ANSWER QUESTION 1 and any other 1 QUESTION

Show your work clearly and answer the sub-questions in the order asked.

34
50

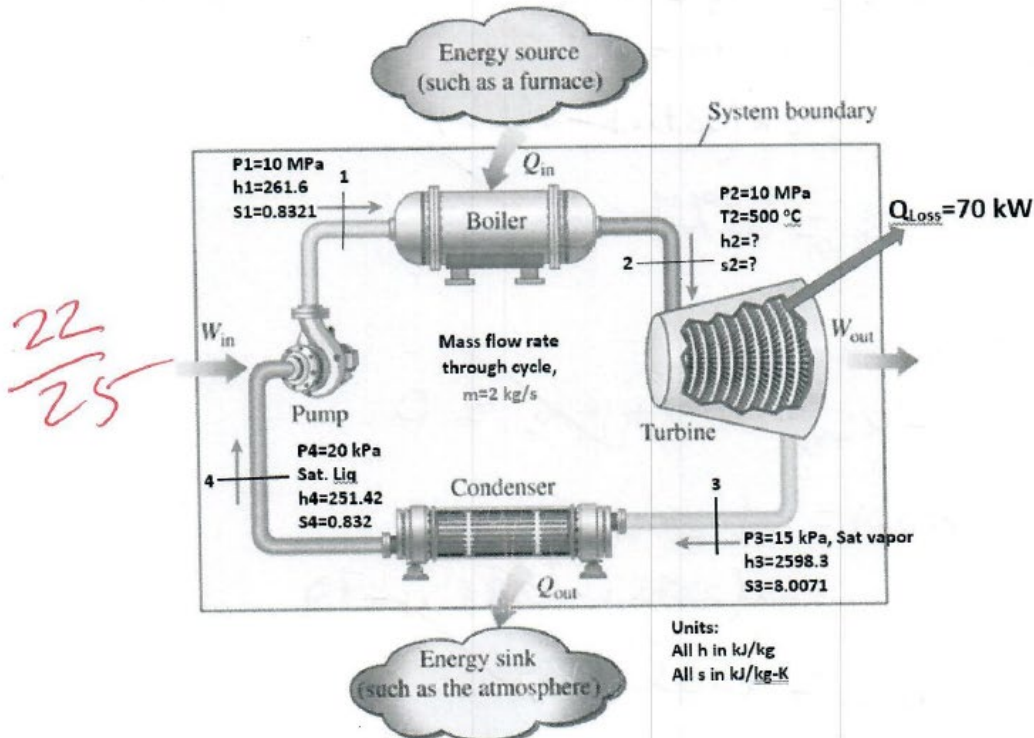
Name Safiatou Zampaligre

12/07/2021

By writing my name above, I understand and agree that any dishonesty on this exam will result in an "F" grade in the course.

QUESTION 1 [25 Points]

For the steam power cycle shown in the Figure, the mass flow rate of water through the cycle is 2 kg/s. All of the properties at the various state points are indicated in the Figure.



- Find the specific enthalpy h_2 and the specific entropy, s_2 at state 2 from your steam Tables. **Double check your answers to ensure you have read the table correctly.**
- By making an energy balance on the boiler, calculate the rate of heat input to the boiler, Q_{in} in kW
- By making an energy balance on the turbine, calculate the power output of the turbine W_{out} in kW
- By making an energy balance on the condenser, calculate the rate of heat rejected from the condenser, Q_{out} in kW
- By making an energy balance on the pump, calculate the power input to the pump, W_{in} in kW
- calculate the net power output, W_{net} in kW
- Calculate the thermal efficiency of the cycle
- Determine S_{gen} for the Turbine in kW/K and indicate if the turbine process is possible or impossible, reversible or irreversible. Assume the turbine is losing heat to the surroundings at $T_o=300$ K
- Determine S_{gen} for the condenser in kW/K if the heat is lost to the surroundings at $T_o=300$ K and indicate if the condenser process is possible or impossible, reversible or irreversible.

$$a) \left. \begin{array}{l} P_2 = 10 \text{ MPa} \\ T_2 = 500^\circ\text{C} \end{array} \right\} \Rightarrow \begin{array}{l} h_2 = 3375.1 \text{ kJ/kg} \\ s_2 = 6.5995 \text{ kJ/kgK} \end{array}$$

$$b) E_{in} - E_{out} = 0$$

$$m \cdot h_1 + Q_{in} = m \cdot h_2$$

$$\begin{aligned} Q_{in} &= m \cdot h_2 - m \cdot h_1 \\ &= m(h_2 - h_1) \\ &= 2 \times (3375.1 - 261.6) \end{aligned}$$

$$Q_{in} = 6227 \text{ kW}$$

$$c) E_{in} - E_{out} = 0$$

$$m \cdot h_2 - (Q_{loss} + W_{out} + m \cdot h_3) = 0$$

$$\begin{aligned} \Rightarrow W_{out} &= m(h_2 - h_3) - Q_{loss} \\ &= 2 \times (3375.1 - 2598.3) - 70 \end{aligned}$$

$$W_{out} = 1483.6 \text{ kW}$$

$$d) E_{in} - E_{out} = 0$$

$$m \cdot h_3 - (Q_{out} + m \cdot h_4) = 0$$

$$\begin{aligned} Q_{out} &= m(h_3 - h_4) \\ &= 2 \times (2598.3 - 251.42) \end{aligned}$$

$$Q_{out} = 4693.76 \text{ kW}$$

$$e) E_{in} - E_{out} = 0$$

$$m h_u + \dot{W}_{in} - m h_1 = 0$$

$$\dot{W}_{in} = m(h_1 - h_u)$$

$$= 2 \times (261.1 - 251.42)$$

$$\dot{W}_{in} = 19.36 \text{ kW}$$

7y)

$$\dot{W}_{net} = \dot{W}_{out} - \dot{W}_{in}$$

$$= 1483.6 - 19.36$$

$$\dot{W}_{net} = 1464.24 \text{ kW}$$

$$y) \eta = \frac{\dot{W}_{net}}{\dot{Q}_{in}} = \frac{1464.24}{(4693.76 + 62.97)}$$

$$= 0.3549$$

$$= 35.49\%$$

$$h) S_{gen} = (m s_2 - m s_1) + \frac{\dot{Q}}{T_b}$$

$$= 2(6.5995 - 8.0071) - \frac{70}{300}$$

$$= -3.004 < 0 = \text{possible but irreversible}$$

$$S_{gen} = m(s_3 - s_4) + \frac{\dot{Q}_{out}}{T_b}$$

$$= 2(8.0071 - 0.832) \left(\frac{4693.76}{300} \right)$$

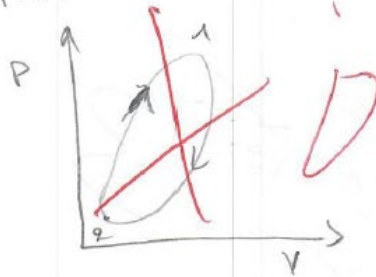
$$= 224.52 > 0 \text{ Impossible}$$

QUESTION 3 [25 Points]

Air contained in a piston cylinder arrangement is expanded in a polytropic process from $P_1=900\text{ kPa}$, $V_1=0.05\text{ m}^3$, $T_1=400\text{ }^\circ\text{C}$ to $P_2=170\text{ kPa}$. The polytropic index, $n=1.2$. Assume that the air is an ideal gas with constant specific heats and that $R=0.287\text{ kJ/kg}\cdot\text{K}$, $c_p=1.005\text{ kJ/kg}\cdot\text{K}$ and $c_v=0.718\text{ kJ/kg}\cdot\text{K}$.

- Show the process on a $P=V$ diagram
- Calculate the final total volume V_2 , in m^3 .
- Calculate the work done, W in kJ and indicate the direction of the work as input or output. Make a sketch of the system and indicate the direction of the work
- Calculate the mass of air in the system in kg .
- Calculate the final temperature, T_2 , in K .
- Applying energy balance to the system, calculate the heat transfer, Q in kJ and indicate whether it is heat input or output. Show the direction of the heat input or output on a sketch of the system.
- Calculate the entropy change of the system in kJ/K .
- Calculate the entropy change of the surroundings if the surrounding is at $T_0=300\text{ K}$.
- Calculate S_{gen} and from the value of S_{gen} , indicate whether the process is possible or impossible, reversible or irreversible.

a) show the process on a $P=V$ diagram



a) Calculate the final

$$V_2 = V_1 \left(\frac{P_1}{P_2} \right)^{\frac{1}{n}}$$

$$= 0.05 \left(\frac{900}{170} \right)^{\frac{1}{1.2}}$$

$$V_2 = 0.200\text{ m}^3$$

Calculate work done

$$W = \frac{P_2 V_2 - P_1 V_1}{1 - n} = \frac{170 \times 0.2 - 900 \times 0.05}{1 - 1.2} = 53\text{ kJ}$$

$$V_1 = 55 \text{ KJ}$$

$$d) P_1 V_1 = n R T_1$$

$$n = \frac{P_1 V_1}{R T_1}$$

$$n = \frac{900 \times 0.05}{0.287 \times 673.15}$$

$$n = 0.23 \text{ kg}$$

$$T_1 = 400^\circ\text{C} + 273.15 = 673.15 \text{ K}$$

$$e) P_2 V_2 = n R T_2$$

$$T_2 = \frac{P_2 V_2}{n R}$$

$$= \frac{170 \times 0.2}{0.23 \times 0.287}$$

$$T_2 = 515.07 \text{ K}$$

$$f) E_{in} - E_{out} = E_2 - E_1$$

AVERAGE

23+37 = 60 %

Score for this quiz: **23** out of 50

Submitted Dec 7 at 6pm

This attempt took 54 minutes.

Question 1

4 / 4 pts

A fan accelerates air from a velocity of 0 m/s to a velocity of 15 m/s at a volume flow rate of 5 m³/s. If the density of the air is 1.2 kg/m³, the minimum power needed for the fan in Watts is

Correct!

675

Correct Answers

675 (with margin: 10)

Additional Comments:

Question 2

3 / 3 pts

A 7.5 m³ rigid vessel contains water at 10 MPa, and 400 °C. The mass of water in the vessel in kg is

Correct!

283.7

Correct Answers

283.7 (with margin: 1)

Question 3

3 / 3 pts

During a heating process, the temperature of an object rises by 250 °C. This temperature rise in °F is

Correct!

450

Correct Answers

450 (with margin: 5)

Additional Comments:

Question 4

4 / 4 pts

Helium is in a 5.0 ft³ container at a temperature of 12.35 °R and pressure of 66.4 psia. For helium, the critical pressure, $P_c=33.2$ psia, and the critical temperature, $T_c=9.5$ °R. Calculate the reduced temperature and reduced pressure and use these to determine the value of Z from the compressibility chart. The value of Z read from the chart is approximately (Note: the compressibility chart is in chapter 3, page 137 and in Figure A-15 on page 906 of the textbook).

Write down your answer for Z for use in the next question.

☐ 0.30

Correct!

☒ 0.7☐ 0.8☐ 1.0☐ 0.45

Question 5

0 / 3 pts

Helium is in a 5.0 ft^3 container at a temperature of 12.35°R and pressure of 66.4 psia . For helium, the critical pressure, $P_c=33.2 \text{ psia}$, and the critical temperature,

$T_c=9.5^\circ\text{R}$. Using the compressibility factor Z you obtained in the previous question, if for helium $R=0.4961 \text{ Btu/lbm-}^\circ\text{R}$, the computed mass of the helium in the tank in lbm is

You Answered

☒ 54.2☐ 67.7

Correct Answer

☐ 77.41☐ 120.4☐ 180.6

Question 6

3 / 3 pts

If P is the pressure, v is the specific volume, T is the temperature, R is the specific gas constant and Z is the compressibility factor, which of the following statements represents the ideal gas law

☐ $Pv=ZRT$ as long as $Z>0$

Correct!

☒ $Pv=ZRT$ if $Z=1$ ☐ $Pv=ZRT$ if Z is any number☐ $Pv=ZRT$ if $Z>1$ ☐ $Pv=ZRT$ if $Z<1$

Question 7

0 / 3 pts

An engineer claims he has designed an engine that takes in 7500kJ of heat from a reservoir at 400 °C and rejects heat to a reservoir at 27 °C with a net work output of 3000 kJ. The % efficiency of this engine is

Write down computed efficiency of the engine for use in question 9

You Answered

40

Correct Answers

60 (with margin: 2)

Additional Comments:

Question 8

3 / 3 pts

An engineer claims he has designed an engine that takes in 7500kJ of heat from a reservoir at 400 °C and rejects heat to a reservoir at 27 °C with a net work output of 3000 kJ. The % efficiency of a Carnot engine operating between the two given temperatures is

Write down computed efficiency of the Carnot engine for use in question 9

Correct!

55

Correct Answers

55 (with margin: 2)

Question 9

0 / 3 pts

An engineer claims he has designed an engine that takes in 7500 kJ of heat from a reservoir at 400 °C and rejects heat to a reservoir at 27 °C with a net work output of 3000 kJ. From your answers for the efficiency of the engine in question 7 and that of the Carnot engine operating between the same two temperatures in question 8, which of the statements is true about his claim.

- ☐ the engine is possible but reversible
- ☐ the engine is impossible
- ☐ the engine is impossible but reversible
- ☒ the engine is possible but irreversible

☐ (E) none of the above

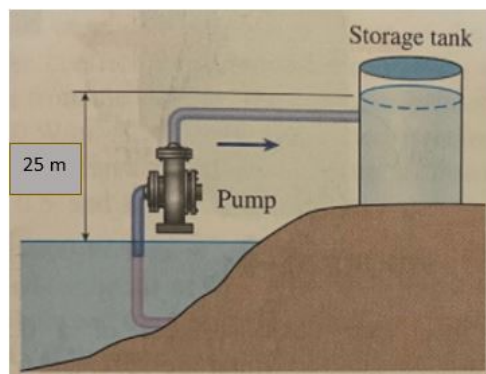
Correct Answer

You Answered

Question 10

0 / 4 pts

Water of density 1000 kg/m³ is pumped from a lake to a storage tank as shown in the Figure at a location where $g = 9.81 \text{ m/s}^2$. The volume flow rate of the water is 0.1 m³/s and the electrical power input to motor driving the pump is 27 kW. The overall efficiency of the pump-motor unit in % is



You Answered

81

Correct Answers

90.8 (with margin: 5)

Question 11

0 / 4 pts

2.5 kg of helium is in a piston cylinder arrangement with an initial volume, $V_1 = 3.5 \text{ m}^3$. The helium is compressed to a final volume of 1 m^3 while its pressure is maintained constant at 250 kPa.

The absolute value of the work done during this constant pressure process in kJ is

Correct Answer

☐ 625☐ 150☐ -525

You Answered

☒ 525☐ -375

Additional Comments:

Question 12

3 / 3 pts

A **closed rigid tank** contains air at $P_1 = 700 \text{ kPa}$ and $T_1 = 300^\circ\text{C}$. As a result of heat transfer to the surroundings, the temperature inside the tank drop to 100°C . The work done during the process in kJ is

Correct!

0

Correct Answers

0 (with margin: 1)

Unanswered

Question 13

0 / 4 pts

A piston cylinder device initially contains 0.5 m^3 of air at $P_1=900 \text{ kPa}$, $T_1=200^\circ\text{C}$. The air is **isothermally** expanded to a final volume, $V_2=1.5 \text{ m}^3$. The work done during the process in kJ is

You Answered

Correct Answers

494.4 (with margin: 10)

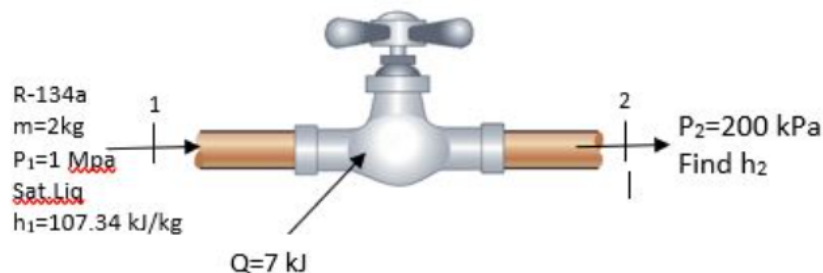
Additional Comments:

Unanswered

Question 14

0 / 3 pts

2 kg of refrigerant R-134a passes through the throttle valve shown. The properties at the inlet are provided on the figure. The refrigerant gains an amount of heat, $Q=7 \text{ kJ}$ as it flows through the valve.



By making an energy balance on the system, the computed value of the enthalpy at the exit state 2, h_2 in kJ/kg is

You Answered

Correct Answers

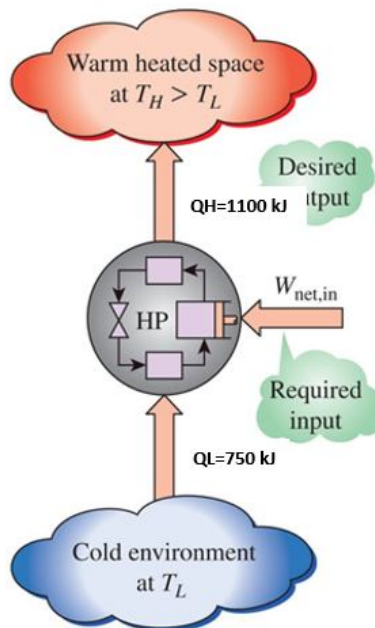
110.8 (with margin: 2)

Unanswered

Question 15

0 / 3 pts

The refrigeration cycle shown in the Figure is used to extract $Q_L = 750$ kJ of heat from the cold space and rejects $Q_H = 1100$ kJ to warm environment. By first making an energy balance on the refrigerator to determine $W_{\text{net,in}}$, determine the COP_{Ref} for this refrigerator.



You Answered

Correct Answers

2.14 (with margin: 0.5)

Make-Up Test Part A Worksheet

Name Tyson Morris

Write the question number followed by your solution

By writing my name above, I understand and agree that any dishonesty on this exam will result in an "F" grade in the course.

$$1) \Delta p_{\text{nozzle}} = \frac{V_2^2 - V_1^2}{2} = \frac{15^2 - 0^2}{2} = \frac{225}{2} = 112.5 \text{ J/kg}$$

$$\text{Power} = \dot{m} \Delta e \quad \dot{m} = \rho \dot{V} \\ (6)(112.5) \quad \dot{m} = (0.2)(5) \\ \boxed{675 \text{ W}} \quad \dot{m} = 0$$

$$2) v = \frac{V}{m} \quad V = 10 \text{ km/h} = 4.5 \text{ m/s} = 0.0254 \text{ m/s} \\ m = \frac{V}{v} = \frac{7.5}{0.0254} \\ \boxed{m = 285.7 \text{ kg}}$$

$$3) 1.8 \Delta C = \Delta F \\ 1.8(250) = \boxed{\Delta F = 450^\circ \text{F}}$$

$$4) P_R = \frac{P}{P_0} = \frac{66.9}{33.2} = 2 \\ T_C = \frac{T}{T_0} = \frac{12.35}{9.5} = 1.3 \\ \boxed{Z = 0.7}$$

$$5) PV = mRT \quad 12.35 \text{ K} \times \frac{5}{9} = \text{K} \\ (66.4)(5.0) = m(0.4461)(0.7801) \\ 332 = m(3.404) \\ \boxed{59.2 \text{ g} = m}$$

$$7) \eta = \frac{W_{\text{out}}}{W_{\text{in}}} = \frac{3000}{7500} = 0.4 = \boxed{40\%}$$

$$8) \eta_{\text{th, cv}} = 1 - \frac{T_L}{T_H} \quad \frac{400 - 273}{273 - 273} = 0.75 \\ 1 - \frac{300}{475} = 0.55 = \boxed{55\%}$$

$$10) W_{\text{in}} = 27 \text{ kW} \quad \dot{m} = \rho \dot{V} \\ (1000)(0.1) \\ \dot{m} = 100 \text{ kg/s} \\ P_{\text{out}} = \dot{m} \Delta e \\ (100)(218.25) \\ P_{\text{out}} = 21825 \text{ W} \\ P_{\text{in}} = 21.825 \text{ kW} \\ \Delta e_{\text{max}} = \Delta P E \\ g(Z_2 - Z_1) \\ (9.81)(25) \\ 245.25 \text{ J/kg} \\ \Delta e = 245.25 - 27 = 218.25 \text{ J/kg}$$

$$\eta = \frac{P_{\text{out}}}{P_{\text{in}}} = \frac{21.825}{27} = 0.81 = \boxed{81\%}$$

$$11) W = \frac{V_2^2 - V_1^2}{2} \quad V_1 = \frac{2.5}{2.5} = 1.4 \text{ m/s} \\ V_2 = \frac{1}{2.5} = 0.4 \text{ m/s}$$

$$13) W = \frac{V_2^2 - V_1^2}{2} = \frac{1.5^2 - 0.5^2}{2} = 1 \text{ J} \\ E = \frac{1}{2} m V^2$$

THERMODYNAMICS I
FALL 2021 FINAL EXAM PART B
ANSWER QUESTION 1 and any other 1 QUESTION

Show your work clearly and answer the sub-questions in the order asked.

37
50

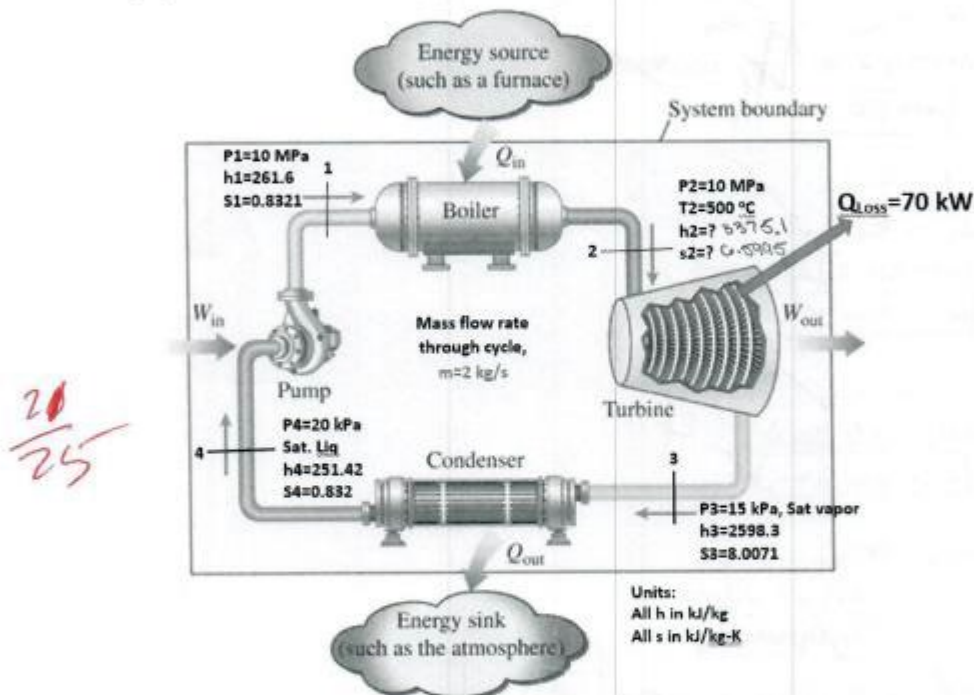
Name Tyson Morris

12/07/2021

By writing my name above, I understand and agree that any dishonesty on this exam will result in an "F" grade in the course.

QUESTION 1 [25 Points]

For the steam power cycle shown in the Figure, the mass flow rate of water through the cycle is 2 kg/s. All of the properties at the various state points are indicated in the Figure.



- Find the specific enthalpy h_2 and the specific entropy, s_2 at state 2 from your steam Tables. *Double check your answers to ensure you have read the table correctly.*
- By making an energy balance on the boiler, calculate the rate of heat input to the boiler, Q_{in} in kW
- By making an energy balance on the turbine, calculate the power output of the turbine W_{out} , in kW
- By making an energy balance on the condenser, calculate the rate of heat rejected from the condenser, Q_{out} in kW
- By making an energy balance on the pump, calculate the power input to the pump, W_{in} , in kW
- calculate the net power output, W_{net} , in kW
- Calculate the thermal efficiency of the cycle
- Determine S_{gen} for the Turbine in kW/K and indicate if the turbine process is possible or impossible, reversible or irreversible. Assume the turbine is losing heat to the surroundings at $T_o=300$ K
- Determine S_{gen} for the condenser in kW/K if the heat is lost to the surroundings at $T_o=300$ K and indicate if the condenser process is possible or impossible, reversible or irreversible.

a) $h_2 = 3375.1 \text{ kJ/kg}$
 $T_2 = 6.5995 \text{ kJ/kg}$

b) $E_{in} = E_{out}$
 $m h_1 + Q_2 = m h_2$
 $2(201.5) + Q_{in} = 2(3375.1)$
 $403.0 + Q_{in} = 6750.2$
 $Q_{in} = 6227 \text{ kW}$

c) $E_{in} = E_{out}$
 $m h_2 = Q_{in} + W + m h_3$
 $2(3375.1) = 70 + W + 2(201.5)$
 $1488.6 \text{ kW} = W_{out}$

d) $E_{in} = E_{out}$
 $m h_3 = Q_{out} + m h_4$
 $2(201.5) = Q_{out} + 2(251.42)$
 $4695.76 \text{ kW} = Q_{out}$

e) $m h_4 + W_{in} = m h_3$
 $2(251.42) + W_{in} = 2(201.5)$
 $W_{in} = 20.36 \text{ kW}$

f) $W_{net} = \sum W_{out}$
 $= 1488.6 + 4695.76$
 6177.36 kW

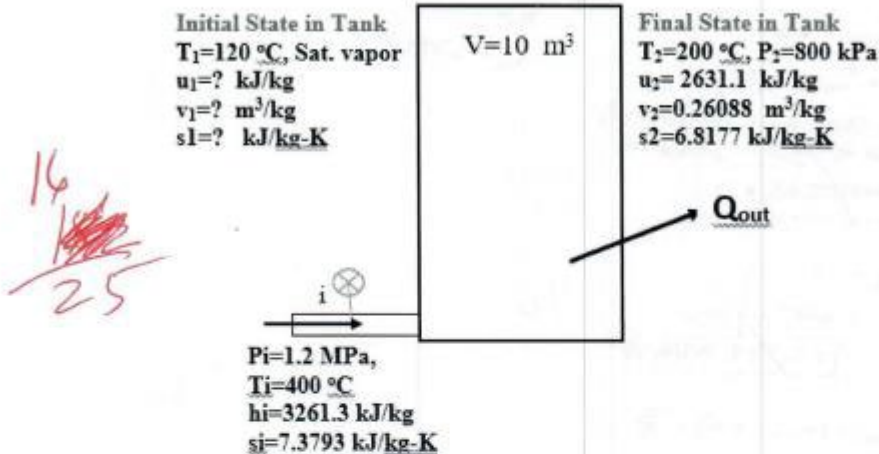
g) $\eta_{net} = \frac{W_{net}}{Q_{in}} = \frac{6177.36}{6227.36} = 0.9918 = 99.18\%$

h) $S_{gen} = \Delta S_{sys} + \Delta S_{surr}$
 $(m_2 s_2 - m_1 s_1) + (m_3 s_3 - m_4 s_4) - \frac{Q_2}{T_1}$
 $(2(6.5995) - 2(0.5995)) + (2(0.2015) - 2(0.5995)) - \frac{70}{298}$
 $2.7152 + 2.7152 - 0.235$
 5.397 kJ/kg

possible, irreversible

QUESTION 2 [25 Points]

A rigid tank of volume 10 m^3 initially contains saturated water vapor at a temperature of 120°C . Steam at a pressure 1.2 MPa and a temperature of 400°C enters the tank through a valve in steam line that is connected to the tank until the final pressure in the tank is 800 kPa , at which time the temperature is 200°C . All kinetic and potential energy effects can be neglected. A schematic of the problem and properties at all state points except state 1 are shown in the figure below.



- Given that the initial state of the steam is a saturated vapor at $T_1 = 120^\circ\text{C}$, read the values of the specific volume, v_1 , specific internal energy, u_1 , and the specific entropy, s_1 at state 1
- Calculate the initial mass, m_1 , of steam in the tank in kg
- Calculate the final mass, m_2 , of steam in the tank in kg
- By making a mass balance on the control volume, calculate the mass of steam that entered the tank, m_i , in kg
- By making an energy balance on the system and assuming the system lost heat as shown on the diagram, compute the heat lost Q_{out} during the process in kJ
- Calculate the entropy change of the system, ΔS_{system} in kJ/K
- Calculate the entropy change of the surrounding, ΔS_{sur} in kJ/K, if the heat is lost to the surrounding at $T_b = 300 \text{ K}$
- Calculate the entropy generated, S_{gen} in kJ/K
- From your answer for S_{gen} , explain whether the process as described is possible or impossible, reversible or irreversible.

a) $v_1 = 0.89133 \text{ m}^3/\text{kg}$
 $u_1 = 2528.9 \text{ kJ/kg}$
 $s_1 = 7.1292 \text{ kJ/kg}\cdot\text{K}$

b) $v_1 = \frac{V}{m_1}$
 $0.89133 = \frac{10}{m_1}$
 $m_1 = 11.22 \text{ kg}$

c) $v_2 = \frac{V}{m_2}$
 $0.26088 = \frac{10}{m_2}$
 $m_2 = 38.3 \text{ kg}$

d) $m_2 - m_1 = \Delta m = m_i$
 $38.3 - 11.22 = \Delta m = m_i$
 $\boxed{27.08 \text{ kg} = \Delta m = m_i}$

e) $E_{in} = E_{out}$
 $m h_1 = Q_{out} + m h_2$
 $(11.22)(1700) = Q_{out} + (38.3)(2899.8)$
 $30301.82 = Q_{out} + 108064.04$
 $\boxed{-78953.02 \text{ kJ} = Q_{out}}$

$h_1 = 2706.0$
 $h_2 = 2899.8$

f) $\Delta S_{sp} = S - S_i$
 $= 0.3177 - 7.1292$
 $\boxed{-0.3115 \text{ kJ/kg} \cdot \text{K}}$

g) $\Delta S_{sur} = (m e_{20} - m_i) - \frac{Q_i}{T_i}$
 $-0.3115 + (10)(0) - (11.22)(7.1292) = \frac{-78953.02}{-300}$
 $\boxed{3411.02 \text{ kJ/kg} \cdot \text{K}}$

h) $S_{gen} = \Delta S_{sp} + \Delta S_{sur}$
 $-0.3115 + 3411.02$
 $\boxed{3407.1 \text{ kJ/kg} \cdot \text{K}}$

i) possible, irreversible why? $\frac{1}{2}$

Make-Up Test Part A Worksheet

Name Safiatou Zampaligue

Write the question number followed by your solution

By writing my name above, I understand and agree that any dishonesty on this exam will result in an "F" grade in the course.

$$2.) \rho = \frac{V}{V} = \frac{7.5 \text{ m}^3}{0.626436 \text{ km}^3/\text{kg}} = 283.70 \text{ kg}$$

$$3.) = 250^\circ\text{C}$$

$$\Delta T = 250 \times 1.8$$

$$= 450^\circ\text{F}$$

15.)

$$\text{COP}_{\text{ref}} = \frac{Q_L}{Q_H - Q_L}$$

$$= \frac{750}{1100 - 750}$$

$$= 2.14$$

13.)

$$W = P_1 V_1 \ln \frac{V_2}{V_1}$$

$$= 800 \text{ kg} \times 0.5 \ln \left(\frac{1.5}{0.5} \right)$$

$$= 494.375 \text{ KJ}$$

$$12.) W = 0 \text{ KJ rigid}$$

11.)

$$7.) \eta = 1 - \frac{Q_L}{Q_H}$$

$$\% \eta = 1 - \frac{3000}{7500}$$

$$= 0.6$$

$$= 60\%$$

$$8.) \eta = 1 - \frac{T_L}{T_H}$$

$$= 1 - \frac{27}{100}$$

$$= 0.93$$

$$10.) Q = 100 \text{ kg}$$

$$g = 9.81 \text{ m/s}^2$$

$$\rho = 0.1 \text{ m}^3/\text{s}$$

$$\dot{m} = \rho \cdot V$$

$$e = g \cdot h$$

$$P = \dot{m} \cdot e$$

$$= \rho \times V \times g \cdot h$$

$$= 1000 \times 0.1 \times 9.81 \times 25$$

$$= 24525 \text{ W} = 24.525 \text{ K}$$

$$\eta_0 = \frac{P_{out}}{P_{in}}$$

$$= \frac{240.525}{274} = 0.8083$$

$$= 80.83\%$$

$$W = \frac{P_1 + P_2}{2} (v_2 - v_1)$$

$$n = \frac{v_1}{v_2} = \frac{v_1}{v_2}$$

$$v_1 = \frac{3.5}{2.5} = 1.4$$

$$v_2 = \frac{1}{2.5} = 0.4$$

1.1)

$$W = \int_1^2 P dv$$

$$= P (v_2 - v_1)$$

$$= 250 (1 - 3.5)$$

$$= -1625 \text{ kJ}$$

14

1.)

$$Q = 0 \text{ mL}$$

$$v = 1.5 \text{ mL}$$

$$\dot{v} = 5 \text{ mL}$$

$$\rho = 1.215 \text{ g/mL}$$

$$P = \rho \cdot v \cdot e \quad \dot{m} = \rho \cdot \dot{v}$$

$$e = \frac{1}{2} v^2$$

$$P = \rho \cdot v \times \frac{1}{2} v^2$$

$$= 1.2 \times 5 \times \left(\frac{1}{2}\right) \times (1.5)^2$$

$$= 675 \text{ mJ}$$

1k.)

$$E_{in} - E_{out} = E_2 - E_1 = 0$$

$$m_1 \times h_1 + Q - m_2 \times h_2 = 0$$

$$h_2 = \frac{m_1 \times h_1 + Q}{m_2}$$

$$= \frac{2 \times 10^7 \times 34 + 7}{2} = 110.84$$

$$h_2 = 110.84 \text{ kJ/kg}$$

BELOW AVERAGE

13+16.5 = 29.5 %

Score for this quiz: **13** out of 50

Submitted Dec 7 at 6pm

This attempt took 54 minutes.

Question 1

0 / 4 pts

A fan accelerates air from a velocity of 0 m/s to a velocity of 15 m/s at a volume flow rate of 5 m³/s. If the density of the air is 1.2 kg/m³, the minimum power needed for the fan in Watts is

You Answered

45

Correct Answers

675 (with margin: 10)

Additional Comments:

Question 2

0 / 3 pts

A 7.5 m³ rigid vessel contains water at 10 MPa, and 400 °C. The mass of water in the vessel in kg is

You Answered

1,114.41

Correct Answers

283.7 (with margin: 1)

Question 3

3 / 3 pts

During a heating process, the temperature of an object rises by 250 °C. This temperature rise in °F is

Correct!

450

Correct Answers

450 (with margin: 5)

Additional Comments:

Question 4

4 / 4 pts

Helium is in a 5.0 ft³ container at a temperature of 12.35 °R and pressure of 66.4 psia. For helium, the critical pressure, $P_c=33.2$ psia, and the critical temperature, $T_c=9.5$ °R. Calculate the reduced temperature and reduced pressure and use these to determine the value of Z from the compressibility chart. The value of Z read from the chart is approximately (Note: the compressibility chart is in chapter 3, page 137 and in Figure A-15 on page 906 of the textbook).

Write down your answer for Z for use in the next question.

Correct!

☐ 0.30☒ 0.7☐ 0.8☐ 1.0☐ 0.45

Question 5

0 / 3 pts

Helium is in a 5.0 ft^3 container at a temperature of 12.35°R and pressure of 66.4 psia . For helium, the critical pressure, $P_c = 33.2 \text{ psia}$, and the critical temperature,

$T_c = 9.5^\circ\text{R}$. Using the compressibility factor Z you obtained in the previous question, if for helium $R = 0.4961 \text{ Btu/lbm-}^\circ\text{R}$, the computed mass of the helium in the tank in lbm is

☐ 54.2☐ 67.7☐ 77.41

Correct Answer

☒ 120.4

You Answered

☐ 180.6

Question 6

0 / 3 pts

If P is the pressure, v is the specific volume, T is the temperature, R is the specific gas constant and Z is the compressibility factor, which of the following statements represents the ideal gas law

☐ $Pv = ZRT$ as long as $Z > 0$ ☐ $Pv = ZRT$ if $Z = 1$ ☐ $Pv = ZRT$ if Z is any number☐ $Pv = ZRT$ if $Z > 1$

Correct Answer

☒ $Pv = ZRT$ if $Z < 1$

You Answered

Question 7

0 / 3 pts

An engineer claims he has designed an engine that takes in 7500kJ of heat from a reservoir at 400 °C and rejects heat to a reservoir at 27 °C with a net work output of 3000 kJ. The % efficiency of this engine is

Write down computed efficiency of the engine for use in question 9

You Answered

0.6

Correct Answers

60 (with margin: 2)

Additional Comments:

Question 8

0 / 3 pts

An engineer claims he has designed an engine that takes in 7500kJ of heat from a reservoir at 400 °C and rejects heat to a reservoir at 27 °C with a net work output of 3000 kJ. The % efficiency of a Carnot engine operating between the two given temperatures is

Write down computed efficiency of the Carnot engine for use in question 9

You Answered

0.6

Correct Answers

55 (with margin: 2)

Question 9

0 / 3 pts

An engineer claims he has designed an engine that takes in 7500 kJ of heat from a reservoir at 400 °C and rejects heat to a reservoir at 27 °C with a net work output of 3000 kJ. From your answers for the efficiency of the engine in question 7 and that of the Carnot engine operating between the same two temperatures in question 8, which of the statements is true about his claim.

You Answered

☒ the engine is possible but reversible

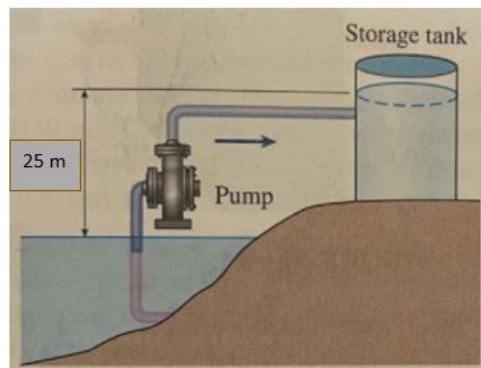
Correct Answer

- ☐ the engine is impossible
- ☐ the engine is impossible but reversible
- ☐ the engine is possible but irreversible
- ☐ (E) none of the above

Question 10

0 / 4 pts

Water of density 1000 kg/m³ is pumped from a lake to a storage tank as shown in the Figure at a location where $g = 9.81 \text{ m/s}^2$. The volume flow rate of the water is 0.1 m³/s and the electrical power input to motor driving the pump is 27 kW. The overall efficiency of the pump-motor unit in % is



You Answered

0.091

Correct Answers

90.8 (with margin: 5)

Question 11

0 / 4 pts

2.5 kg of helium is in a piston cylinder arrangement with an initial volume, $V_1 = 3.5 \text{ m}^3$. The helium is compressed to a final volume of 1 m^3 while its **pressure is maintained constant at 250 kPa**.

The absolute value of the work done during this constant pressure process in kJ is

Correct Answer

☐ 625☐ 150☐ -525

You Answered

☒ 525☐ -375

Additional Comments:

Question 12

3 / 3 pts

A closed rigid tank contains air at $P_1 = 700 \text{ kPa}$ and $T_1 = 300^\circ\text{C}$. As a result of heat transfer to the surroundings, the temperature inside the tank drop to 100°C . The work done during the process in kJ is

Correct!

Correct Answers

0 (with margin: 1)

Question 13

0 / 4 pts

A piston cylinder device initially contains 0.5 m^3 of air at $P_1=900 \text{ kPa}$, $T_1=200^\circ\text{C}$. The air is **isothermally** expanded to a final volume, $V_2=1.5 \text{ m}^3$. The work done during the process in kJ is

You Answered

0

Correct Answers

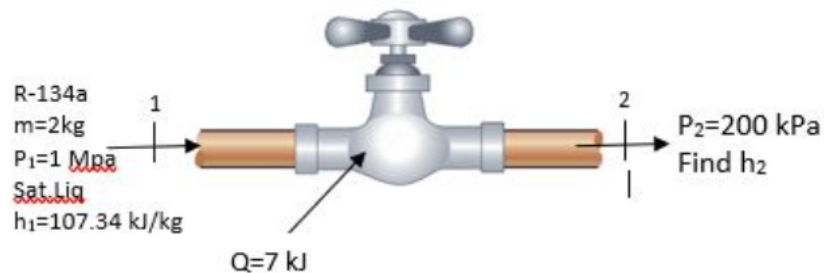
494.4 (with margin: 10)

Additional Comments:

Question 14

0 / 3 pts

2 kg of refrigerant R-134a passes through the throttle valve shown. The properties at the inlet are provided on the figure. The refrigerant gains an amount of heat, $Q=7 \text{ kJ}$ as it flows through the valve.



By making an energy balance on the system, the computed value of the enthalpy at the exit state 2, h_2 in kJ/kg is

You Answered

207.68

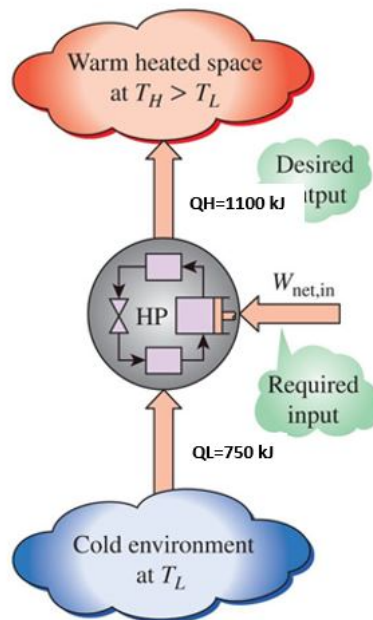
Correct Answers

110.8 (with margin: 2)

Question 15

3 / 3 pts

The refrigeration cycle shown in the Figure is used to extract $Q_L=750$ kJ of heat from the cold space and rejects $Q_H=1100$ kJ to warm environment. By first making an energy balance on the refrigerator to determine $W_{\text{net,in}}$, determine the COP_{Ref} for this refrigerator.



Correct!

2.142

Correct Answers

2.14 (with margin: 0.5)

THERMODYNAMICS I
FALL 2021 FINAL EXAM PART B
ANSWER QUESTION 1 and any other 1 QUESTION

Show your work clearly and answer the sub-questions in the order asked.

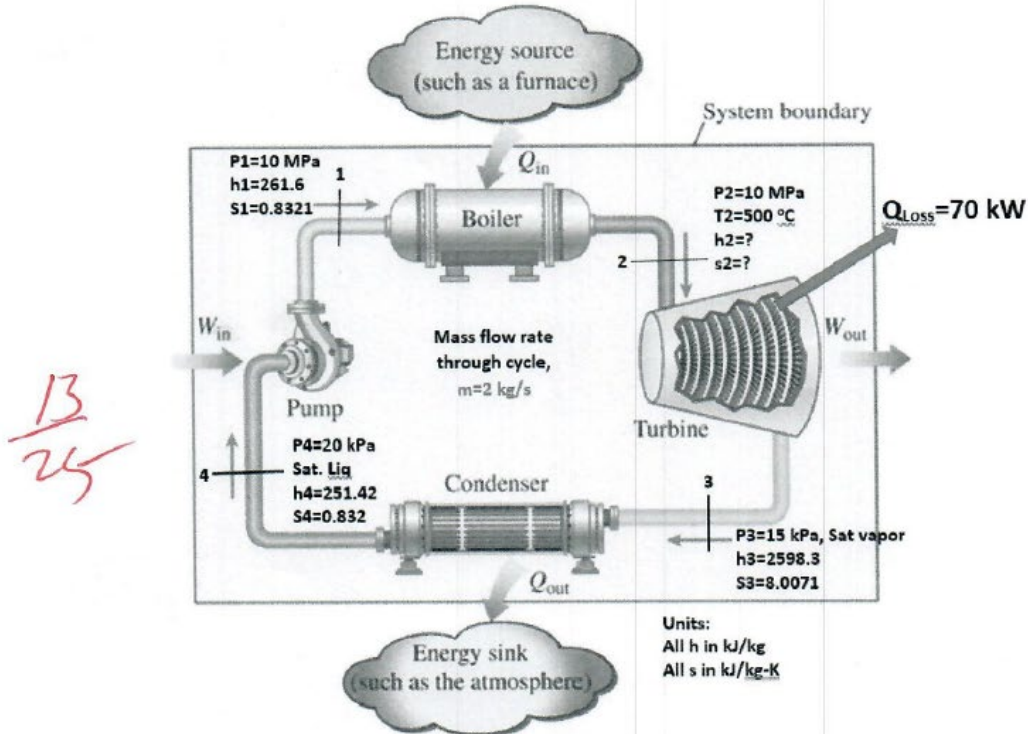
Name Noah Smith Jr.

12/07/2021

By writing my name above, I understand and agree that any dishonesty on this exam will result in an "F" grade in the course.

QUESTION 1 [25 Points]

For the steam power cycle shown in the Figure, the mass flow rate of water through the cycle is 2 kg/s. All of the properties at the various state points are indicated in the Figure.



- Find the specific enthalpy h_2 and the specific entropy, s_2 at state 2 from your steam Tables. **Double check your answers to ensure you have read the table correctly.**
- By making an energy balance on the boiler, calculate the rate of heat input to the boiler, Q_{in} in kW
- By making an energy balance on the turbine, calculate the power output of the turbine W_{out} , in kW
- By making an energy balance on the condenser, calculate the rate of heat rejected from the condenser, Q_{out} in kW
- By making an energy balance on the pump, calculate the power input to the pump, W_{in} , in kW
- calculate the net power output, W_{net} , in kW
- Calculate the thermal efficiency of the cycle
- Determine S_{gen} for the Turbine in kW/K and indicate if the turbine process is possible or impossible, reversible or irreversible. Assume the turbine is losing heat to the surroundings at $T_o = 300$ K
- Determine S_{gen} for the condenser in kW/K if the heat is lost to the surroundings at $T_o = 300$ K and indicate if the condenser process is possible or impossible, reversible or irreversible.

$$a, \quad h_2 = 3375.1 \quad 3 \quad F_{r1} \quad w_{out} - w_{in} = L_{het}$$

$$S = 6.5995$$

$$b, \quad E_{in} - E_{out}$$

$$\dot{m} \cdot h_1 + \overset{Q_{in}}{\text{boiler}} = \dot{m} h_2$$

$$\text{boiler} = \dot{m} (h_1 + h_2)$$

$$= 2 (261.6 + 3375.1)$$

$$= 6227$$

$$c, \quad E_{in} - E_{out}$$

$$\dot{m}_1 h_2 = w_{out} + Q_{LOSS} + \dot{m} h_3$$

$$\dot{m}_1 h_2 - \dot{m} h_3 = 70 \text{ kW} \quad E_1 \quad 1$$

$$2 \times 3375.1 - 2598.3 = 70 \text{ kW} + ? \quad \text{What are you solving for?}$$

$$D, \quad E_{in} - E_{out}$$

$$\dot{m}_3 h_3 - Q_{out} + h_4 \quad ??$$

$$Q_{out} = \dot{m} (h_3 - h_4)$$

$$= 2 (2598.3 - 251.92)$$

$$= 4693.76 \text{ Units?}$$

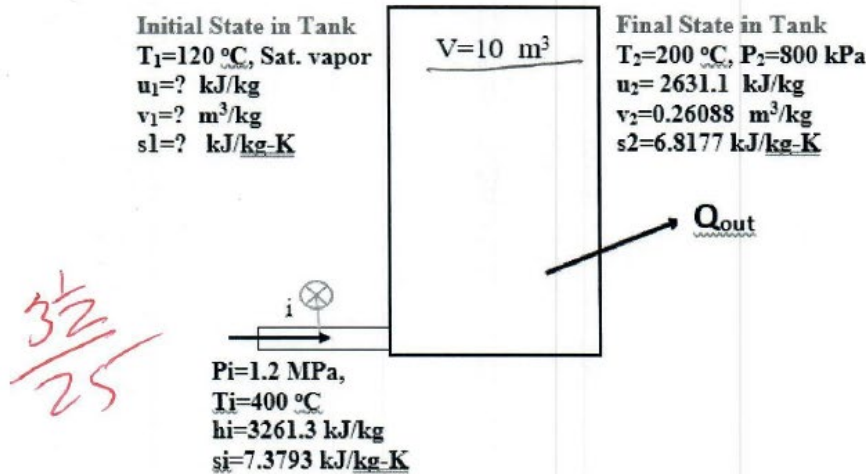
$$E, \quad E_{in} - E_{out}$$

$$\dot{m} h_4 + \overset{w_{in}}{\text{win}} = \dot{m} h_1 \quad h_1 - h_4$$

$$\text{win} = \dot{m} (h_1 - h_4) = 2 (3375.1 - 251.92)$$

QUESTION 2 [25 Points]

A rigid tank of volume 10 m^3 initially contains saturated water vapor at a temperature of 120°C . Steam at a pressure 1.2 MPa and a temperature of 400°C enters the tank through a valve in steam line that is connected to the tank until the final pressure in the tank is 800 kPa , at which time the temperature is 200°C . All kinetic and potential energy effects can be neglected. A schematic of the problem and properties at all state points except state 1 are shown in the figure below.



- Given that the initial state of the steam is a saturated vapor at $T_1=120^\circ\text{C}$, read the values of the specific volume, v_1 , specific internal energy, u_1 , and the specific entropy, s_1 at state 1
- Calculate the initial mass, m_1 , of steam in the tank in kg
- Calculate the final mass, m_2 , of steam in the tank in kg
- By making a mass balance on the control volume, calculate the mass of steam that entered the tank, m_i , in kg
- By making an energy balance on the system and assuming the system lost heat as shown on the diagram, compute the heat lost Q_{out} during the process in kJ
- Calculate the entropy change of the system, ΔS_{system} in kJ/K
- Calculate the entropy change of the surrounding, ΔS_{surr} in kJ/K, if the heat is lost to the surrounding at $T_b=300 \text{ K}$
- Calculate the entropy generated, S_{gen} in kJ/K
- From your answer for S_{gen} , explain whether the process as described is possible or impossible, reversible or irreversible.

Handwritten calculations:

1. $v_g = 0.89133 \text{ m}^3/\text{kg}$ (from steam tables at 120°C)

2. $m_1 = \frac{V}{v_1} = \frac{10}{0.89133} = 11.219 \text{ kg}$

3. $m_2 = \frac{V}{v_2} = \frac{10}{0.26088} = 38.33 \text{ kg}$

4. $m_i = m_2 - m_1 = 38.33 - 11.219 = 27.11 \text{ kg}$

5. $Q_{\text{out}} = m_1 u_1 + m_i h_i - m_2 u_2$

6. $Q_{\text{out}} = 11.219 \times u_1 + 27.11 \times 3261.3 - 38.33 \times 2631.1$

7. $Q_{\text{out}} = 11.219 \times 2528.9 + 27.11 \times 3261.3 - 38.33 \times 2631.1$

8. $Q_{\text{out}} = 28619.5 + 88414.5 - 100744.5 = 16689.5 \text{ kJ}$

9. $\Delta S_{\text{system}} = m_2 s_2 - m_1 s_1 - m_i s_i$

10. $\Delta S_{\text{system}} = 38.33 \times 6.8177 - 11.219 \times 7.127 - 27.11 \times 7.3793$

11. $\Delta S_{\text{system}} = 261.2 - 80.0 - 200.0 = -18.8 \text{ kJ/K}$

12. $\Delta S_{\text{surr}} = \frac{Q_{\text{out}}}{T_b} = \frac{16689.5}{300} = 55.6 \text{ kJ/K}$

13. $S_{\text{gen}} = \Delta S_{\text{system}} + \Delta S_{\text{surr}} = -18.8 + 55.6 = 36.8 \text{ kJ/K}$

14. The process is irreversible because $S_{\text{gen}} > 0$.

$$F_1 \quad E_{in} - E_{out} = E_2 - E_1$$

$$6,8177 - 7,1292 = 7,3793 - E_2$$

$E_{out} \quad E_{in} \quad -E_1$

$$= -0,042212676$$

$$E_1 \quad E_{in} - E_{out} = E_2 - E_1$$

$$120 = 200 = E_2 - 400$$

$$= 480$$

THERMODYNAMICS I
FALL 2021

Title of Assignment: QUIZ 1

ABOVE AVERAGE

Score for this quiz: **20** out of 20
Submitted Aug 24 at 5:47pm
This attempt took 2 minutes.

20/20

Question 1

5 / 5 pts

What is the study of Thermodynamics about?

- ☐ E. The fluids used to convert work to heat
- ☐ C. Fluids
- ☐ B. Work
- ☒ D. Heat, work, and the fluids used to convert heat to work
- ☐ A. Conversion of work to heat

Correct!

Additional Comments:

Question 2

5 / 5 pts

The most **abundant** form of energy is **work** and the most **useful** form of energy is **heat**.

- ☐ True
- ☒ False

Correct!

1 gallon of water at 200 °C has higher quality of energy than the whole Pacific ocean that has an average temperature of 12 °C.

Correct!

☒ True

☐ False

Additional Comments:

Question 4

5 / 5 pts

What is a closed system?

☐ D. Mass cannot cross the boundary

☐ B. Mass cannot enter but mass can leave

☐ A. Mass can enter but cannot leave

☐ C. Mass cannot enter and mass cannot leave

Correct!

☒ E. Both C and D above

Additional Comments:

Fudge Points: --

You can manually adjust the score by adding positive or negative points to this box.

Final Score: 20 out of 20

U

AVERAGE

Score for this quiz: **15** out of 20
Submitted Aug 24 at 5:46pm
This attempt took 1 minute.

15/20

Question 1

5 / 5 pts

What is the study of Thermodynamics about?

- ☐ C. Fluids
- ☐ B. Work
- ☒ D. Heat, work, and the fluids used to convert heat to work
- ☐ E. The fluids used to convert work to heat
- ☐ A. Conversion of work to heat

Correct!

Additional Comments:

Question 2

5 / 5 pts

The most **abundant** form of energy is **work** and the most **useful** form of energy is **heat**.

- ☐ True
- ☒ False

Correct!

Question 3

5 / 5 pts

1 gallon of water at 200 °C has higher quality of energy than the whole Pacific ocean that has an average temperature of 12 °C.

Correct!

☒ True

☐ False

Additional Comments:

Question 4

0 / 5 pts

What is a closed system?

You Answered

☒ C. Mass cannot enter and mass cannot leave

☐ A. Mass can enter but cannot leave

Correct Answer

☐ E. Both C and D above

☐ B. Mass cannot enter but mass can leave

☐ D. Mass cannot cross the boundary

BELOW AVERAGE

10/20

Score for this quiz: **10** out of 20

Submitted Aug 24 at 5:46pm

This attempt took 1 minute.

Question 1

5 / 5 pts

What is the study of Thermodynamics about?

- ☐ A. Conversion of work to heat
- ☐ B. Work
- ☒ D. Heat, work, and the fluids used to convert heat to work
- ☐ E. The fluids used to convert work to heat
- ☐ C. Fluids

Correct!

Additional Comments:

Question 2

5 / 5 pts

The most **abundant** form of energy is **work** and the most **useful** form of energy is **heat**.

- ☐ True
- ☒ False

Correct!

Question 3

0 / 5 pts

1 gallon of water at 200 °C has higher quality of energy than the whole Pacific ocean that has an average temperature of 12 °C.

Correct Answer

☐ True

You Answered

☒ False

Additional Comments:

Question 4

0 / 5 pts

What is a closed system?

Correct Answer

☐ E. Both C and D above

☐ B. Mass cannot enter but mass can leave

☐ A. Mass can enter but cannot leave

You Answered

☒ C. Mass cannot enter and mass cannot leave

☐ D. Mass cannot cross the boundary

THERMODYNAMICS I
FALL 2021

Title of Assignment: QUIZ 3

ABOVE AVERAGE

40/40

Score for this quiz: 40 out of 40

Submitted Sep 9 at 9:20am

This attempt took 8 minutes.

Question 1

10 / 10 pts

1. A boxer weighs 400 lbf. The surface area covered by **each foot** is 50 in^2 . What is the pressure on the floor, in lbf/in^2 , if he stands on ONE foot?

Correct!

- ☒ 8
- ☐ 0.125
- ☐ 4
- ☐ 400
- ☐ 0.625

Additional Comments:

Question 2

5 / 5 pts

2. Which of the following statements describe the Zeroth law of Thermodynamics for three bodies with temperatures T_1 , T_2 , and T_3 .

- ☐ If $T_1=T_2$ and $T_3=0$ Then $T_1=T_3$
- ☐ If $T_1=T_2$, then $T_3=T_1$
- ☐ None of the other answers is correct
- ☐ If $T_2=T_3$, then $T_1=T_2$

Correct!

- ☒ If $T_1=T_2$, and $T_3=T_2$, then $T_1=T_3$

Question 3

5 / 5 pts

3. A system with non-uniform properties can still be in a steady state if the non-uniform properties do not change with time.

Correct!

☒ True☐ False

Additional Comments:

Question 4

10 / 10 pts

4. A system is heated during which the temperature changed by 216 °F. What is this temperature change in K?

☐ 676☐ 393.15☐ 216☐ None of the numerical values provided is right

Correct!

☒ 120

Question 5

10 / 10 pts

5. The pressure between the top and the base of a mountain is 5000 Pa. If the density of the air in the location is 1.2 kg/m^3 and the local gravity is $g=9.81 \text{ m/s}^2$, what is the height of the mountain in **meters**. Provide only numerical answer to 1 decimal place with no units attached.

Correct!

424.7

Correct Answers

0 (with margin: 0)

0 (with margin: 0)

0 (with margin: 0)

424.7 (with margin: 1)

AVERAGE

30/40

Score for this quiz: 30 out of 40

Submitted Sep 9 at 9:18am

This attempt took 6 minutes.

Question 1

0 / 10 pts

1. A boxer weighs 400 lbf. The surface area covered by **each foot** is 50 in^2 . What is the pressure on the floor, in lbf/in^2 , if he stands on ONE foot?

☐ 400

☐ 0.625

☐ 0.125

You Answered

☒ 4

Correct Answer

☐ 8

Additional Comments:

Question 2

5 / 5 pts

2. Which of the following statements describe the Zeroth law of Thermodynamics for three bodies with temperatures T_1 , T_2 , and T_3 .

☐ If $T_1 = T_2$ and $T_3 = 0$ Then $T_1 = T_3$

☐ If $T_2 = T_3$, then $T_1 = T_2$

☐ None of the other answers is correct

☐ If $T_1 = T_2$, then $T_3 = T_1$

Correct!

☒ If $T_1 = T_2$, and $T_3 = T_2$, then $T_1 = T_3$

Question 3

5 / 5 pts

3. A system with non-uniform properties can still be in a steady state if the non-uniform properties do not change with time.

Correct!

☒ True

☐ False

Additional Comments:

Question 4

10 / 10 pts

4. A system is heated during which the temperature **changed by 216 °F**. What is this **temperature change** in K?

Correct!

☐ 393.15

☒ 120

☐ None of the numerical values provided is right

☐ 216

☐ 676

Question 5

10 / 10 pts

5. The pressure between the top and the base of a mountain is 5000 Pa. If the density of the air in the location is 1.2 kg/m^3 and the local gravity is $g=9.81 \text{ m/s}^2$, what is the height of the mountain in **meters**. Provide only numerical answer to 1 decimal place with no units attached.

Correct!

424.7

Correct Answers

0 (with margin: 0)

0 (with margin: 0)

0 (with margin: 0)

424.7 (with margin: 1)

BELOW AVERAGE

10/40

Score for this quiz: **10** out of 40

Submitted Sep 9 at 9:20am

This attempt took 6 minutes.

Question 1

0 / 10 pts

1. A boxer weighs 400 lbf. The surface area covered by **each foot** is 50 in^2 . What is the pressure on the floor, in lbf/in^2 , if he stands on ONE foot?

- ☐ 400
- ☐ 8
- ☐ 0.625
- ☐ 0.125

Correct Answer

You Answered

- ☒ 4

Additional Comments:

Question 2

5 / 5 pts

2. Which of the following statements describe the Zeroth law of Thermodynamics for three bodies with temperatures T_1 , T_2 , and T_3 .

Correct!

- ☒ If $T_1=T_2$, and $T_3=T_2$, then $T_1=T_3$
- ☐ If $T_1=T_2$ and $T_3=0$ Then $T_1=T_3$
- ☐ If $T_1=T_2$, then $T_3=T_1$
- ☐ None of the other answers is correct
- ☐ If $T_2=T_3$, then $T_1=T_2$

Question 3

5 / 5 pts

3. A system with non-uniform properties can still be in a steady state if the non-uniform properties do not change with time.

Correct!

☒ True

☐ False

Additional Comments:

Question 4

0 / 10 pts

4. A system is heated during which the temperature changed by 216 °F. What is this temperature change in K?

☐ 216

Correct Answer

☐ 120

You Answered

☒ 393.15

☐ 676

☐ None of the numerical values provided is right

Unanswered

Question 5

0 / 10 pts

5. The pressure between the top and the base of a mountain is 5000 Pa. If the density of the air in the location is 1.2 kg/m³ and the local gravity is $g=9.81 \text{ m/s}^2$, what is the height of the mountain in **meters**. Provide only numerical answer to 1 decimal place with no units attached.

You Answered

Correct Answers

0 (with margin: 0)
424.7 (with margin: 1)
0 (with margin: 0)
0 (with margin: 0)

THERMODYNAMICS I
FALL 2021

Title of Assignment: QUIZ 5

ABOVE AVERAGE

Score for this quiz: 30 out of 35

Submitted Sep 16 at 9:26am

This attempt took 9 minutes.

Question 1

0 / 5 pts

A system undergoes a process during which its state changed from from P1, v1 to P2, v2. Which of the statement is true about this process?

- A. We can calculate the work done since we know the initial and the final states
- B. Even though the path of the process is not known we can compute the work done by $W=(P2-P1)(v2-v1)$
- C. We cannot compute the work done because the process path is not known
- D. Though we cannot compute the work done, we can compute the heat transfer.
- E. None of the alternatives provided is right

☐ A

You Answered

☒ B

Correct Answer

☐ C☐ D☐ E

Question 2

5 / 5 pts

A system undergoes a process during which its state changed from from T1, v1 to T2, v2. Which of the statements below is true about this process?

- A. We can calculate the temperature change since we know the initial and the final states
- B. Because the path of the process is not known we cannot compute the temperature change
- C. We cannot compute the volume change because the process path is not known
- D. Even though we cannot compute the temperature change, we can compute the volume change
- E. None of the alternatives provided is right

Correct!

☒ A☐ B☐ C☐ D☐ E

Question 3

5 / 5 pts

An **insulated** room is being heated electrically using a heating element. We can say that

- A. There is heat transfer
- B. There is work transfer
- C. There are both heat and work transfers
- D. None of the other answers provide is right

☐ A

☒ B

☐ C

☐ D

Correct!

Additional Comments:

Question 4

10 / 10 pts

An elevator in a high rise building has a mass of 2000 kg when fully loaded with passengers. The elevator motor raises the elevator and the passengers through a height of 900 m from the 1st floor to the 100th floor in 60 seconds. Assume $g=9.81 \text{ m/s}^2$. The power expended by the elevator motor in **kW** is (Do not include units in your answer and correct to 1 decimal place)

Correct!

294.3

Correct Answers

294.3 (with margin: 5)
0 (with margin: 0)
0 (with margin: 0)
0 (with margin: 0)

Question 5

10 / 10 pts

The Tesla Model S which has a mass of 2100 kg is able to accelerate from 0 to 26.82 m/s (i.e. 0-60 mph) in 2.2 seconds. The power developed during this speed change in kW is

Correct!

343.3

Correct Answers

343.3 (with margin: 5)
0 (with margin: 0)
0 (with margin: 0)
0 (with margin: 0)

AVERAGE

Score for this quiz: 25 out of 35

Submitted Sep 16 at 9:28am

This attempt took 11 minutes.

Question 1

0 / 5 pts

A system undergoes a process during which its state changed from from P1, v1 to P2, v2. Which of the statement is true about this process?

- A. We can calculate the work done since we know the initial and the final states
- B. Even though the path of the process is not known we can compute the work done by $W=(P2-P1)(v2-v1)$
- C. We cannot compute the work done because the process path is not known
- D. Though we cannot compute the work done, we can compute the heat transfer.
- E. None of the alternatives provided is right

You Answered☒ A☐ B**Correct Answer**☐ C☐ D☐ E**Question 2**

5 / 5 pts

A system undergoes a process during which its state changed from from T1, v1 to T2, v2. Which of the statements below is true about this process?

- A. We can calculate the temperature change since we know the initial and the final states
- B. Because the path of the process is not known we cannot compute the temperature change
- C. We cannot compute the volume change because the process path is not known
- D. Even though we cannot compute the temperature change, we can compute the volume change
- E. None of the alternatives provided is right

Correct!☒ A☐ B☐ C☐ D☐ E

Question 3

0 / 5 pts

An **insulated** room is being heated electrically using a heating element. We can say that

- A. There is heat transfer
- B. There is work transfer
- C. There are both heat and work transfers
- D. None of the other answers provide is right

☐ A

☐ B

☒ C

☐ D

Correct Answer

You Answered

Additional Comments:

Question 4

10 / 10 pts

An elevator in a high rise building has a mass of 2000 kg when fully loaded with passengers. The elevator motor raises the elevator and the passengers through a height of 900 m from the 1st floor to the 100th floor in 60 seconds. Assume $g=9.81 \text{ m/s}^2$. The power expended by the elevator motor in **kW** is (Do not include units in your answer and correct to 1 decimal place)

Correct!

294.3

Correct Answers

294.3 (with margin: 5)
 0 (with margin: 0)
 0 (with margin: 0)
 0 (with margin: 0)

Question 5

10 / 10 pts

The Tesla Model S which has a mass of 2100 kg is able to accelerate from 0 to 26.82 m/s (i.e. 0-60 mph) in 2.2 seconds. The power developed during this speed change in kW is

Correct!

343.3

Correct Answers

343.3 (with margin: 5)

0 (with margin: 0)

0 (with margin: 0)

0 (with margin: 0)

BELOW AVERAGE

10/35

Score for this quiz: **10** out of 35

Submitted Sep 16 at 9:30am

This attempt took 12 minutes.

Question 1

0 / 5 pts

A system undergoes a process during which its state changed from from P1, v1 to P2, v2. Which of the statement is true about this process?

- A. We can calculate the work done since we know the initial and the final states
- B. Even though the path of the process is not known we can compute the work done by $W=(P_2-P_1)(v_2-v_1)$
- C. We cannot compute the work done because the process path is not known
- D. Though we cannot compute the work done, we can compute the heat transfer.
- E. None of the alternatives provided is right

You Answered

☒ A

☐ B

Correct Answer

☐ C

☐ D

☐ E

Question 2

5 / 5 pts

A system undergoes a process during which its state changed from from T1, v1 to T2, v2. Which of the statements below is true about this process?

- A. We can calculate the temperature change since we know the initial and the final states
- B. Because the path of the process is not known we cannot compute the temperature change
- C. We cannot compute the volume change because the process path is not known
- D. Even though we cannot compute the temperature change, we can compute the volume change
- E. None of the alternatives provided is right

Correct!

☒ A

☐ B

☐ C

☐ D

☐ E

Question 3

5 / 5 pts

An **insulated** room is being heated electrically using a heating element. We can say that

- A. There is heat transfer
- B. There is work transfer
- C. There are both heat and work transfers
- D. None of the other answers provide is right

☐ A

☒ B

☐ C

☐ D

Correct!

Additional Comments:

Unanswered

Question 4

0 / 10 pts

An elevator in a high rise building has a mass of 2000 kg when fully loaded with passengers. The elevator motor raises the elevator and the passengers through a height of 900 m from the 1st floor to the 100th floor in 60 seconds. Assume $g=9.81 \text{ m/s}^2$. The power expended by the elevator motor in **kW** is (Do not include units in your answer and correct to 1 decimal place)

You Answered

Correct Answers

294.3 (with margin: 5)
 0 (with margin: 0)
 0 (with margin: 0)
 0 (with margin: 0)

Unanswered

Question 5

0 / 10 pts

The Tesla Model S which has a mass of 2100 kg is able to accelerate from 0 to 26.82 m/s (i.e. 0-60 mph) in 2.2 seconds. The power developed during this speed change in kW is

You Answered

Correct Answers

343.3 (with margin: 5)
0 (with margin: 0)
0 (with margin: 0)
0 (with margin: 0)

THERMODYNAMICS I
FALL 2021

Title of Assignment: QUIZ 7

ABOVE AVERAGE

Score for this quiz: 25 out of 25

Submitted Sep 30 at 9:19am

This attempt took 4 minutes.

25/25

Question 1

/ 5 pts

Which of these statements describe a gas phase?

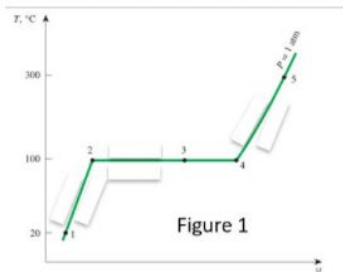
- ☐ A. Intermolecular forces are very strong
- ☐ B. Molecules are kept in fixed position by large attractive force
- ☐ C. Molecules are closer apart to each other
- ☐ D. Molecules are not at fixed positions and are able to translate and rotate freely
- ☒ E. Molecules move about at random, continually colliding with each other

Correct!

Question 2

5 / 5 pts

Which of the following statements correctly labels states 1, 2, 3, 4, and 5 in that order in Figure 1



- ☐ A. 1=saturated liquid, 2=compressed liquid, 3=saturated vapor, 4=superheated vapor, 5=saturated vapor
- ☐ B. 1=compressed liquid, 2=saturated vapor, 3=saturated mixture, 4=superheated vapor, 5=saturated liquid
- ☐ C. 1=saturated mixture, 2=compressed liquid, 3=superheated vapor, 4=saturated vapor, 5=saturated liquid
- ☐ D. 1=saturated vapor, 2=saturated liquid, 3=superheated vapor, 4=compressed vapor, 5=saturated mixture
- ☒ E. 1=compressed liquid, 2=saturated liquid, 3=saturated mixture, 4=saturated vapor, 5=superheated vapor

Correct!

Question 3

5 / 5 pts

Saturated liquid water is at a pressure of 1000 kPa. What will be its specific internal energy in kJ/kg?

Correct!

761.39

Correct Answers

761.39 (with margin: 0.1)

0 (with margin: 0)

0 (with margin: 0)

0 (with margin: 0)

Additional Comments:

Question 4

5 / 5 pts

The specific internal energy of water at 5MPa is 417.69 kJ/kg. What is the temperature in oC?

Correct!

100

Correct Answers

100 (with margin: 0.1)

0 (with margin: 0)

0 (with margin: 0)

0 (with margin: 0)

Question 5

5 / 5 pts

The specific volume of water at 400 kPa is $0.25 \text{ m}^3/\text{kg}$. What region is this state in?

☐ compressed liquid

☐ Saturated liquid

☐ superheated vapor

Correct!

☒ saturated mixture

☐ saturated vapor

AVERAGE

Score for this quiz: 20 out of 25

Submitted Sep 30 at 9:23am

This attempt took 8 minutes.

Question 1

5 / 5 pts

Which of these statements describe a gas phase?

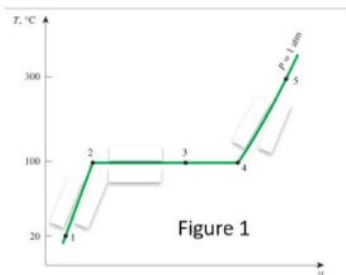
- ☐ A. Intermolecular forces are very strong
- ☐ B. Molecules are kept in fixed position by large attractive force
- ☐ C. Molecules are closer apart to each other
- ☐ D. Molecules are not at fixed positions and are able to translate and rotate freely
- ☒ E. Molecules move about at random, continually colliding with each other

Correct!

Question 2

5 / 5 pts

Which of the following statements correctly labels states 1, 2, 3, 4, and 5 in that order in Figure 1



- ☐ A. 1=saturated liquid, 2=compressed liquid, 3=saturated vapor, 4=superheated vapor, 5=saturated vapor
- ☐ B. 1=compressed liquid, 2=saturated vapor, 3=saturated mixture, 4=superheated vapor, 5=saturated liquid
- ☐ C. 1=saturated mixture, 2=compressed liquid, 3=superheated vapor, 4=saturated vapor, 5=saturated liquid
- ☐ D. 1=saturated vapor, 2=saturated liquid, 3=superheated vapor, 4=compressed vapor, 5=saturated mixture
- ☒ E. 1=compressed liquid, 2=saturated liquid, 3=saturated mixture, 4=saturated vapor, 5=superheated vapor

Correct!

Question 3

0 / 5 pts

Saturated liquid water is at a pressure of 1000 kPa. What will be its specific internal energy in kJ/kg?

You Answered

1,821.4

Correct Answers

761.39 (with margin: 0.1)
0 (with margin: 0)
0 (with margin: 0)
0 (with margin: 0)

Additional Comments:

Question 4

5 / 5 pts

The specific internal energy of water at 5MPa is 417.69 kJ/kg. What is the temperature in oC?

Correct!

100

Correct Answers

100 (with margin: 0.1)
0 (with margin: 0)
0 (with margin: 0)
0 (with margin: 0)

Question 5

5 / 5 pts

The specific volume of water at 400 kPa is $0.25 \text{ m}^3/\text{kg}$. What region is this state in?

- ☐ compressed liquid
- ☐ Saturated liquid
- ☐ superheated vapor
- ☒ saturated mixture
- ☐ saturated vapor

Correct!

BELOW AVERAGE

Score for this quiz: **10** out of 25

Submitted Sep 30 at 9:27am

This attempt took 12 minutes.

Question 1

5 / 5 pts

Which of these statements describe a gas phase?

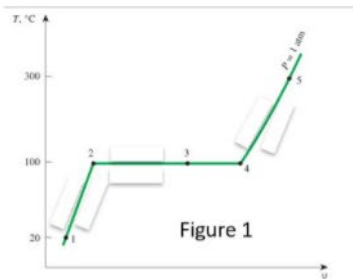
- ☐ A. Intermolecular forces are very strong
- ☐ B. Molecules are kept in fixed position by large attractive force
- ☐ C. Molecules are closer apart to each other
- ☐ D. Molecules are not at fixed positions and are able to translate and rotate freely
- ☒ E. Molecules move about at random, continually colliding with each other

Correct!

Question 2

5 / 5 pts

Which of the following statements correctly labels states 1, 2, 3, 4, and 5 in that order in Figure 1



- ☐ A. 1=saturated liquid, 2=compressed liquid, 3=saturated vapor, 4=superheated vapor, 5=saturated vapor
- ☐ B. 1=compressed liquid, 2=saturated vapor, 3=saturated mixture, 4=superheated vapor, 5=saturated liquid
- ☐ C. 1=saturated mixture, 2=compressed liquid, 3=superheated vapor, 4=saturated vapor, 5=saturated liquid
- ☐ D. 1=saturated vapor, 2=saturated liquid, 3=superheated vapor, 4=compressed vapor, 5=saturated mixture
- ☒ E. 1=compressed liquid, 2=saturated liquid, 3=saturated mixture, 4=saturated vapor, 5=superheated vapor

Correct!

Question 3

0 / 5 pts

Saturated liquid water is at a pressure of 1000 kPa. What will be its specific internal energy in kJ/kg?

You Answered

53,648

Correct Answers

761.39 (with margin: 0.1)

0 (with margin: 0)

0 (with margin: 0)

0 (with margin: 0)

Additional Comments:

Question 4

0 / 5 pts

The specific internal energy of water at 5MPa is 417.69 kJ/kg. What is the temperature in °C?

You Answered

93

Correct Answers

100 (with margin: 0.1)

0 (with margin: 0)

0 (with margin: 0)

0 (with margin: 0)

Question 5

0 / 5 pts

The specific volume of water at 400 kPa is 0.25 m³/kg. What region is this state in?

☐ compressed liquid

☐ Saturated liquid

You Answered

☒ superheated vapor

Correct Answer

☐ saturated mixture

☐ saturated vapor

THERMODYNAMICS I

FALL 2021

HOMEWORK #1 QUESTIONS

Introduction and Basic Concepts

Formal: Problems Problem 1.15 [(a)Energy=12 kWh or 43,200 kJ},,],

Problem 1-37E [45 R, 25 K, 25 oC]

Problem 1-55 [850m], 1.58 [P=147 kPa],

Problem 1-67E [P=18.1 psia],

Problem 1.78 [h=0.582 m],

Problem 1-90 [D2=0.872 m],

Problem 1-110 [P=354.6 kPa],

Problem 1-113 [P=79.0 kPa],

Problem 1-116,

Problem 1-117E

ABOVE AVERAGE

80/80=100 %

1-37E

Temitayo Ojo
Christopher scales

L.C. Hollies
Keigan Kenney
Clayton Strickling

Problem statement:

The temperature of a system drops by 45°F during a cooling process. Express this drop in temperature in K, R, and $^\circ\text{C}$.

Known:

Temperature change in F = 45°F

Find:

Express this drop in temperature in K, R, and $^\circ\text{C}$

Schematic: no sketch

Assumptions:

I am assuming the temperature dropped during a cooling process and we are trying to find the same drop of temp in K, R, $^\circ\text{C}$.

Properties: All needed properties are known

Analysis:

Physical law/Equation -

$$F \text{ to } K \Rightarrow K = (^\circ\text{F} - 32) \times \frac{5}{9} + 273.15$$

$$T_1^\circ\text{F} = T_1^\circ\text{R} - 459.67$$

$$T_1^\circ\text{F} - T_2^\circ\text{F} = (T_1^\circ\text{R} - 459.67) - (T_2^\circ\text{R} - 459.67)$$

$$\Delta T(^{\circ}\text{F}) = \Delta T(^{\circ}\text{R})$$

Solution plan -

$$\Delta T(^{\circ}\text{R}) = 45^{\circ}\text{R}$$

$$\Delta T(\text{K}) = \frac{\Delta T(^{\circ}\text{R})}{1.8} = \frac{45}{1.8} = 25 \text{ K}$$

$$\Delta T(\text{K}) = 25 \text{ K}$$

$$\text{and } \Delta T(^{\circ}\text{C}) = \Delta T(\text{K}) = 25^{\circ}\text{C}$$

Comments:

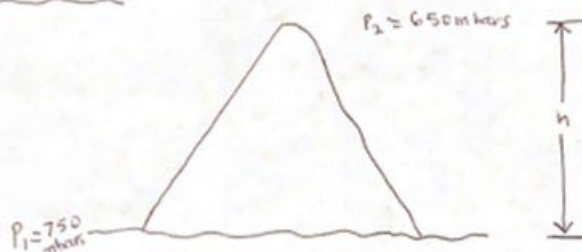
Temperature change in Celsius and Kelvin scales are also

Problem Statement

The barometer of a mountain hiker reads 750 mbars at the beginning of a hiking trip and 650 mbars at the end. Neglecting the effect of altitude on local gravitational acceleration, determine the vertical distance climbed. Assume an average air density of 1.20 kg/m^3 .

Find

Required to find/determine the vertical distance climbed.

SchematicAssumptions

Assume an average air density of 1.20 kg/m^3 .

Properties: All needed Properties are known

Analysis

Physical law/Equation -

$$P_2 - P_1 = -\rho g h$$

Sub 750 mbars for P_1 , 650 mbars for P_2 , 1.20 kg/m^3 for ρ , and 9.81 m/s^2 for g .

Solution plan -

$$(650 \times 10^{-3} \times 10^3) - (750 \times 10^{-3} \times 10^3) = -1.2(9.81)h$$

$$h = \frac{-1000}{(-1.2(9.81))}$$

$$h = \underline{850 \text{ m}}$$

Comment

Therefore, the vertical distance climbed by the mountain hiker is 850 m.

Problem Statement:

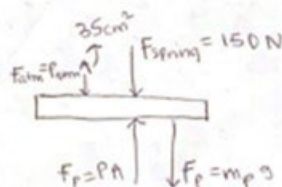
A gas is contained in a vertical, frictionless piston cylinder device. The piston has a mass of 3.2 kg and a cross sectional area of 35 cm^2 . A compressed spring above the piston exerts a force of 150 N on the piston. If the atmospheric pressure is 95 kPa, determine the pressure inside the cylinder.

Known:

Exerts a force of 150 N on the piston.
~~Determine the pressure inside the cylinder~~
 Piston has mass of 3.2 kg and a cross sectional area of 35 cm^2 .

Find:

determine the pressure inside the cylinder

Schematic:Assumptions:

If the atmospheric pressure is 95 kPa

Properties: All needed properties are known

Analysis:

Physical laws/Equation-

$$P = P_{\text{atm}} + P_{\text{spring}} + P_{\text{piston}}$$

Solution plan:-

$$P_{\text{atm}} = 95 \text{ kPa}$$

$$P_{\text{spring}} = \frac{150}{35 \times 10^{-4}} = 42.8571 \text{ kPa}$$

$$P_{\text{piston}} = \frac{mg}{A} = \frac{3.2 \times 9.81}{35 \times 10^{-4}} = 8.9691$$

$$P = 146.826 \text{ kPa} \approx 147 \text{ kPa}$$

Comments:

I changed/rounded up the answer.

Problem Statement:

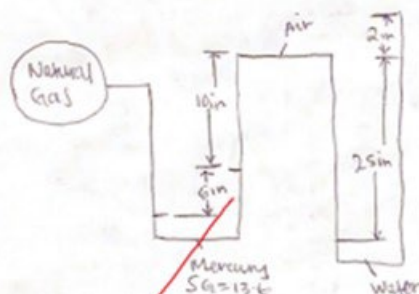
The pressure in a natural gas pipeline is measured by the manometer shown in Fig. P1-67E with one of the arms open to the atmosphere where the local atmospheric pressure is 14.2 psia. Determine the absolute pressure in the pipeline.

Known:

Mercury SG = 13.6
local atmospheric is 14.2 psia

Find:

Determine the absolute pressure in the pipeline

Schematic:assumptions:

Pressure in a natural gas pipeline is measured by the manometer, so air is assumed to be mixed with both.

Properties: All needed properties are known

Analysis:

Physical laws/equation -

$$P_N - \rho_H g h_H - \rho_W g h_W = P_{atm}$$

Solution Plan -

$$h_H = 6 \text{ in}, h_W = 27 \text{ in}$$

$$P_N = [(948.6 \times 32.2 \times 6/12) + (62.4 \times 32.2 \times 27/12)] \left(\frac{1}{32.2 \times 144} \right) + 14.2$$

$$= 18.122 \text{ psia}$$

Comments:

The absolute pressure ended up to being = 18.122 psia

Problem Statement:

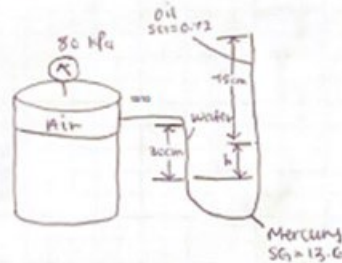
The gage pressure of the air in the tank shown in Fig. P1-78 is measured to be 80 kPa. Determine the differential height h of the mercury column.

Known:

gage pressure = 80 kPa
 $S_G = 0.72$ (oil)
 Mercury $S_G = 13.6$

Find:

Determine the differential height h of the mercury column.

Schematic:Assumptions:

Pressure is assumed to increase if we go below the given plane and decrease if we go above the reference plane.

Properties:

All needed properties are known.

Analysis:

Physical Laws/Equations-

$$P_A + \rho_{oil} g h_{oil} + \rho_{Hg} g h - \rho_{water} g h_{water} = P_{air, abs}$$

Pressure = $\rho g h$

$$P_A + (\rho_{water} g h_1) - (\rho_{oil} g h_2) - (\rho_{Hg} g h_3) = P_B = 0 \quad P_B = 0 \quad g = 9.81 \text{ m/s}^2$$

Solution Plan-

$$(80 \times 10^3) + (1000 \times 9.81 \times 0.3) - (13600 \times 9.81 \times h) - (720 \times 9.81 \times 0.75) = 0$$

$$77645.5 = 133416 h$$

$$h = 0.5819 \text{ m}$$

Comments:

Since $P_{air, gage}$ is in kPa, each $\rho g h$ term (which is in Pa) needs to be divided by 1000 to convert them to kPa.

Problem Statement:

A hydraulic lift is to be used to lift a 1900-kg weight by putting a weight of 25 kg on a piston with a diameter of 10 cm. Determine the diameter of the piston on which the weight is to be placed.

Knowns:

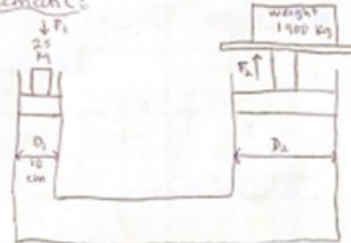
$$\text{Weight} = 1900 \text{ kg } (m_2) \quad D_2 = ?$$

$$\text{Weight} = 25 \text{ kg } (m_1)$$

$$D_1 = 10 \text{ cm} = 0.1 \text{ m}$$

Find:

determine the diameter of the piston on which the weight is to be placed.

Schematic:Assumptions:

No assumptions.

Properties & all needed properties are known

Analysis:

Physical laws/Equations -

$$P_1 = P_2 \quad \frac{F_1}{A_1} = \frac{F_2}{A_2} \quad \frac{m_1 g}{\frac{\pi}{4} d_1^2} = \frac{m_2 g}{\frac{\pi}{4} d_2^2} \Rightarrow d_2^2 = \frac{d_1^2 \times m_2 g}{m_1 g}$$

Solution plan -

$$d_2^2 = \frac{(0.1)^2 \times 1900 \times 9.81 \times 1000}{25 \times 9.81 \times 1000}$$

$$d_2^2 = 0.76$$

$$d_2 = \sqrt{0.76} = 0.871779 \text{ m}$$

Comments:

Note Give units chance cm to m .

Problem Statement:

A gasoline line is connected to a pressure gage through a double manometer, as shown in Fig. P1-110. If the reading of the pressure gage is 370 kPa, determine the gage pressure of the gasoline line.

Known:

density of water $\rho_w = 1000 \text{ kg/m}^3$

density of oil $\rho_o = 0.79 \times 1000 = 790 \text{ kg/m}^3$

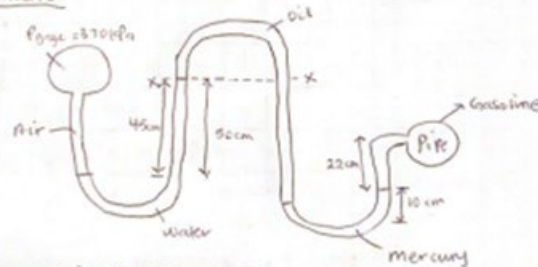
density of mercury $\rho_m = 13.6 \times 1000 = 13600 \text{ kg/m}^3$

density of gasoline $\rho_g = 0.70 \times 1000 = 700 \text{ kg/m}^3$

$P_{\text{gage}} = 370 \text{ kPa}$

Find:

determine the gage pressure of the gasoline line.

Schematic:

Assumptions: NO assumptions.

Properties: All needed properties are known.

Analysis:

Physical laws/Equations -

$$P_{\text{gage}} + \rho_{\text{air}} g h_{\text{air}} - \rho_w g h_1 + \rho_{\text{oil}} g h_2 + \rho_{\text{Hg}} g h_3 - \rho_g g h_4 = P_{\text{gas}}$$

Solution Plan -

$$P_{\text{gage}} - (\rho_w g \times 45/100) = P + (\rho_g g \times 22/100) + (\rho_m g \times 14/100) - (\rho_g g \times 59/100)$$

$$P = 354.608 \text{ kPa}$$

Comments:

Therefore, gage pressure of gasoline line is $P = 354.608 \text{ kPa}$

1-115

Temilayo Ojo

Christian Santos

Clayton Stalling

L.C. Holmes

Kelgan Kennedy

Problem Statement

Pressure transducers are commonly used to measure pressure by generating analog signals usually in the range of 4 mA to 20 mA or 0 V-dc in response to applied pressure. The system whose schematic is shown in Fig P1-113 can be used to calibrate pressure transducers. A rigid container is filled with pressurized air, and pressure is measured by the manometer attached. A valve is used to regulate the pressure in the container. Both the pressure and the electric signal are measured simultaneously for various settings, and the results are tabulated. For the given set of measurements, obtain the calibration curve in the form of $P = aI + b$, where a and b are constants and calculate and pressure that corresponds to a signal of 10 mA.

Known

$\Delta h = 28 \text{ mm}$
Corresponding pressure 10 mA

Find

Obtain the calibration curve in the form of $P = aI + b$, where a and b are constants and calculate and pressure that corresponds to a signal of 10 mA.

Schematic

Assumptions

no assumptions.

Properties

All needed properties are known

Analysis

Physical law/Equation -
 $P = 13600 \times 9.81 \times 0.028$

Solution Plan -
 $= 3755.648 \text{ N/m}^2$
 $= 3.755 \text{ kN/m}^2$
 $= 3.755 \text{ kPa}$

Comments
 Therefore, the pressure corresponds to a signal of 10 mA is 79.236 kPa

AVERAGE

Hunter Evans
Darrian Scull
Manuel Reyes

Sapiatov
Zampaligre
Jordan Joubert

Problem 1-15

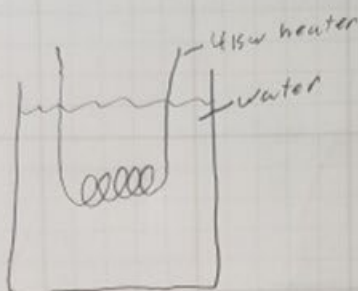
1/7

Problem 1-15: A 4-kW resistance heater in a water heater runs for 3 hours to raise the water temp. to the desired level. Determine the amount of electric energy used in both kWh and kJ.

Known: Power, 4 kW ; Time, 3 hours.

Find: Amount of electric energy used, kWh and kJ.

Schematic:



Assumption: Over time the energy consumption to make the water hotter will increase.

Properties: All needed Properties are known.

Analysis:

Equations: $P = \frac{E}{T}$
 $E = P \cdot T$

OK

10/10

Solution: $E = 4 \text{ kW} \cdot 3 \text{ hrs} = \boxed{12 \text{ kWh}}$

$$E = 12 \left(\frac{\text{kJ}}{\text{s}} \right) \cdot (3600 \text{ s}) = \boxed{43200 \text{ kJ}}$$

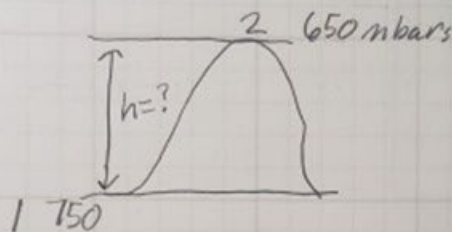
Comments: None.

Problem 1-55: The Barometer of a mountain hiker reads 750 mbars at the beginning of a hiking trip and 650 mbars at the end. Neglecting the effect of altitude on local gravitational acceleration, determine the vertical distance climbed. Assume an average air density of 1.20 kg/m^3 .

Known: atmosphere, $atm_1 = 750$, $atm_2 = 650$; air den. = 1.20 kg/m^3

Find: Determine the vertical distance climbed, h .

Schematic:



Assumptions: the higher you go in the atmosphere the air density lessens.

Properties: $g = 9.81 \text{ m/s}^2$

Analysis:

Equation: $P_1 - \rho_{air} g h = P_2$

10/10

$$\rho_{air} g h = P_1 - P_2$$

$$h = (P_1 - P_2) / (\rho_{air} g)$$

Solution: $h = \frac{(750 \times 10^3) - (650 \times 10^3) \text{ bar}}{(1.20 \text{ kg/m}^3 \cdot 9.81 \text{ m/s}^2)} \cdot 100,000$

$$h = 850 \text{ m}$$

Comments: The 100,000 was a conversion to get the answer.

Problem 1-78

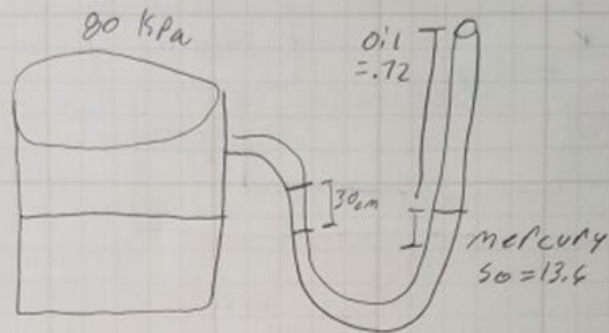
3/7

Statement: The gage pressure of the air in the tank is measured to be 80 kPa. Find the differential height of the mercury column.

Known: pressure, 80 kPa; mercury SG, 13.6; Oil SG, .72

Find: Answer in meters cm

Schematic:



Assumptions: The pressure will change due to the different densities.

Properties: Need density for ρ_{Hg} , ρ_{oil} .

Analysis: $SG = \frac{\rho_{oil}}{\rho_{H_2O}}$ $\rho = kg/m^3$ $P_1 + \rho_{oil}gh_w - \rho_{Hg}gh_{Hg} - \rho_{oil}gh_oil = P_{atm}$

$$13.6 = \frac{\rho_{Hg}}{1000} = 13600 kg/m^3 = \rho_{Hg}$$

$$.72 = \frac{\rho_{oil}}{1000} = 720 kg/m^3 = \rho_{oil}$$

$$80 \cdot 10^3 + 1000 \cdot 9.81 \cdot 0.3 - 13600 \cdot 9.81 \cdot h_{Hg} - 720 \cdot 9.81 \cdot .75 = 0$$

$$80000 + 2943 - 133416h_{Hg} - 5297.4 = 0$$

$$77645.6 - 133416h_{Hg} = 0$$

$$h_{Hg} = \frac{77645.6}{133416} = \boxed{.5819m}$$

Problem 1-40

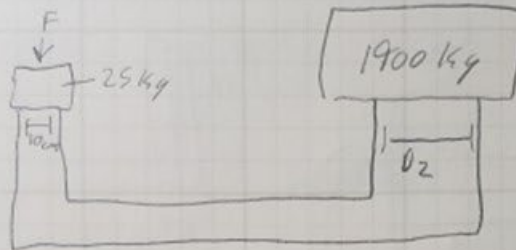
4/7

Statement: Hydraulic lift used to lift 1900 kg weight by putting a weight of 25 kg on a piston with a diameter of 10 cm. Find diameter of piston (D_2)

Known: weight, 25 kg, 1900 kg; diameter, 10 cm

Find: diameter of piston (D_2)

Schematic:



Assumption: D_2 could equal 80 cm

properties: $F = Mg$ $P = \frac{F}{A}$ Pascal's law $P_1 = P_2$

Analysis:

$$P_1 = \frac{25 \cdot 9.81}{\frac{\pi}{4} (0.1)^2} = 31.226 \text{ kN/m}^2$$

$$P_1 = \frac{1900 \cdot 9.81}{\frac{\pi}{4} (x)^2} \rightarrow (x)^2 = \frac{18.639}{\frac{\pi}{4} \cdot P_1} \rightarrow x = \sqrt{\frac{18.639}{\frac{\pi}{4} \cdot P_1}}$$

$$= \sqrt{\frac{18.639}{24524.84}} = \boxed{0.8717 \text{ m}}$$

Problem 1-110

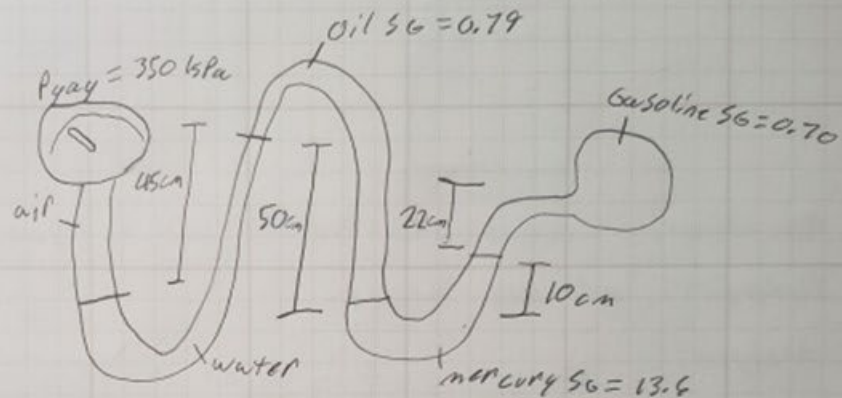
5/7

Statement: a gasoline line is connected to a pressure gage through a double-U manometer, as shown. If the reading of the pressure gage is 350 kPa, determine the gage pressure of the gasoline line.

Known: Pressure, 350 kPa; oil SG, 0.79; mercury SG = 13.6; Gasoline SG, 0.70.

Find: The gage pressure of the gasoline line.

Schematic:



Assumption: none

Properties: all needed properties known.

Analysis:

Water = 1000 kg/m³
 Oil = 790 kg/m³
 mercury = 13600 kg/m³
 Gasoline = 700 kg/m³

$h_1 = 0.45 \text{ m}$
 $h_2 = 0.50 \text{ m}$
 $h_3 = 0.1 \text{ m}$
 $h_4 = 0.22 \text{ m}$

$(P_a)_{\text{gage}} = 350 \cdot 10^3 \text{ Pa}$

$(P_b)_{\text{gage}} = ?$

10/10

$(P_a) - \text{water } \rho g h_1 + \text{oil } \rho g h_2 - \text{mercury } \rho g h_3 - \text{Gasoline } \rho g h_4 = (P_b)$

$$350 \cdot 10^3 - (1000 \cdot 9.81 \cdot 0.45) + (790 \cdot 9.81 \cdot 0.5) - (13600 \cdot 9.81 \cdot 0.1) - (700 \cdot 9.81 \cdot 0.22) = 334608.11$$

$$334608.11 / 1000$$

$$\boxed{334.6 \text{ kPa}}$$

Problem 1-37

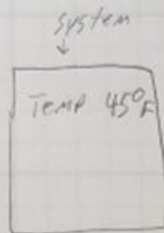
6/7

Statement: The Temperature of a system drops by 45°F during a cooling process. Express this drop in temperature in K , R , and $^{\circ}\text{C}$?

Known: Temp. $^{\circ}\text{F}$, 45°

Find: Temp. K , R , and $^{\circ}\text{C}$.

Schematic:



Assumption: Celsius and Kelvin will be equal

Properties: all are known.

Analysis:

$$F = 45 / 1.8 = ^{\circ}\text{C} = 25^{\circ}\text{C}$$

10/10

$$^{\circ}\text{C} = \text{K}$$

$$\text{R} = \text{F}$$

$$\boxed{^{\circ}\text{C} = 25}$$

$$\boxed{\text{K} = 25}$$

$$\boxed{\text{R} = 45}$$

Problem 1-67

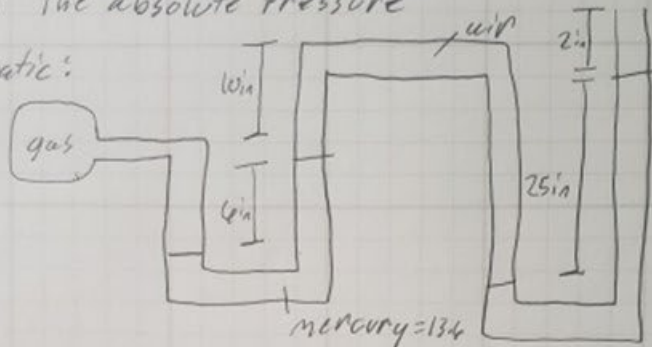
7/7

Statement: The pressure in a natural gas pipeline is measured by the manometer shown, with one of the arms open to the atm. where the local atmospheric pressure is 14.2 psia. Determine the absolute pressure in the pipeline.

Known: Pressure atm, 14.2 psia; mercury SG, 13.6

Find: the absolute pressure

Schematic:



Assumption: none

Properties: all are known

Analysis:

$$P_1 - \rho_{Hg} g h_{Hg} - \rho_w g h_w = P_{atm}$$

$$h_{Hg} = 6 \text{ in}$$

$$h_w = 25 \text{ in}$$

$$P_1 = (848.6 \cdot 32.2 \cdot \frac{6}{12}) + (62.4 \cdot 32.2 \cdot \frac{25}{12}) + 14.2$$

$$P_1 = 18.122 \text{ psia}$$

BELOW AVERAGE

Tyson Morris
Josh Jones
Tyler Rhodes
Valet Teckie
Zack Tynler

p.42

Homework 1: Ch 1

$$56/80 = 70\%$$

1-15) 4 kW for 3 hrs

$$\boxed{12 \text{ kWh}} \quad 7/10$$

$$12 \text{ kWh} \times \frac{3600 \text{ s}}{1 \text{ kWh}} = \boxed{43200 \text{ s}}$$

Use given format

1-37E) $\Delta 45^\circ\text{F}$

$$\Delta R = \Delta F$$

$$\boxed{\Delta R = 45}$$

$$\Delta F = 1.8^\circ\text{F}$$

$$\frac{45}{1.8} = 25$$

$$\boxed{\Delta^\circ\text{C} = 25}$$

$$\Delta K = \Delta^\circ\text{C}$$

$$\boxed{\Delta K = 25}$$

1-55) 1 mbar = 10.197 kg/m²

1 mbar = 100 pa

$$\Delta \text{mbar} = 100 = 1019.7 \text{ kg/m}^2$$

$$P = \rho gh = P_i$$

$$75000 - (1.2)(9.81)h = 65000$$

$$-117.72h = -10000$$

$$\boxed{h = 850}$$

1-58) $PA = P_{\text{atm}}A + mg + F_{\text{spring}}$

7/10

$$P = P_{\text{atm}} + \frac{mg + F_{\text{spring}}}{A}$$

$$= 95 + \frac{(3.2)(9.81) \cdot 150}{35 \cdot 10^{-4}} \left(\frac{1}{1000} \right)$$

$$\boxed{P = 147 \text{ kPa}}$$

$$13.5(62.4 \text{ lbm/ft}^3) = 845.6$$

$$1-67E) \quad P_1 + \overbrace{\rho_1 g h_1}^{\text{mercury}} + \overbrace{\rho_2 g h_2}^{\text{water}} = P_2$$

$$P_1 = P_2 - \rho_1 g h_1 - \rho_2 g h_2$$

$$G_m = 0.1524 \text{ m}$$

$$14.2 + \left((845.6) \left(\frac{7}{10} \right) (0.5 \text{ ft}) \right) + \left((62.4) (32.2) (2.25 \text{ ft}) \right) \left(\frac{1}{32} \right) \left(\frac{1}{144} \right)$$

$$P_1 = 14.2 + 3.9$$

$$\boxed{P_1 = 18.1 \text{ psi}}$$

$$1-78) \quad P_a + \rho_a g h_a - \rho_b g h_b - \rho_c g h_c = 0$$

$$80000 \text{ Pa} + (1000)(9.81)(0.3) - (710)(9.81)h - (720)(9.81)(0.15)$$

$$80000 + 2943 - 133416h - 5297.4$$

$$77645.6 = 133416h$$

$$\boxed{0.582 = h}$$

$$1-90)$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$\frac{m_1 g}{d_1^2} = \frac{m_2 g}{d_2^2}$$

$$d_2^2 = \frac{d_1^2 \cdot m_1 g}{m_2 g}$$

$$(10^4)(1000)(9.81)$$

$$(25)(9.81)$$

$$\sqrt{d_2^2} = \sqrt{77000}$$

$$d_2 = 87.2 \text{ cm}$$

$$\boxed{d_2 = 0.872 \text{ m}}$$

$$1-110) P = \rho g h_1 - \rho g h_2 - \rho g h_3 - \rho g h_4 = P_{gag}$$

$$350000 - (1000)(9.81)(0.45) - (790)(9.81)(0.5) - (13600)(9.81)(0.1) - (700)(9.81)(0.22)$$

$$350000 - 4414.5 - 3874.95 - 13341.6 - 1510.74$$

$$339608.11 \text{ Pa} = P_{gag}$$

$$\boxed{339.6 \text{ kPa} = P_{gag}}$$

$$1-113) P = \rho g A h$$

$$P = (13560)(9.81)(0.028)$$

$$3724.66 \text{ N/m}^2$$

$$3.725 \text{ kN/m}^2$$

$$3.725 \text{ kPa}$$

$$P = 13.039 \text{ I} - 51.154$$

$$P = 13.039(10) - 51.154$$

$$\boxed{79.0 \text{ kPa}}$$

$$1-116) 91.4^\circ\text{F} = 1.8C + 32$$

$$59.4^\circ\text{F} = 1.8C$$

$$33 = C$$

$$\frac{0.0203 \text{ m/s}}{1.009 \text{ m/s}} = 0.0206$$

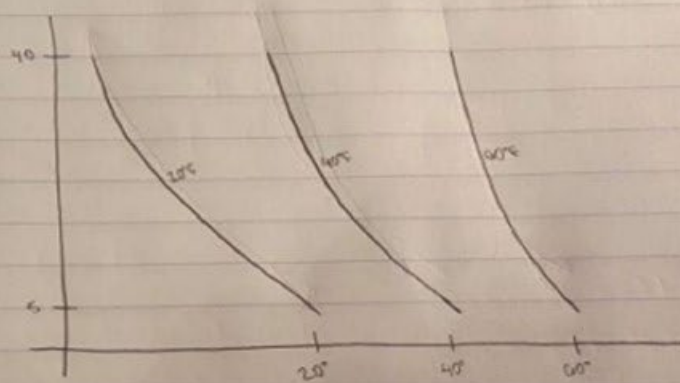
$$0.304 \times \sqrt{\frac{V}{1.009}} = 0.240$$

$$\boxed{T_{equiv} = 33.0 - (33.0 - T_{ambient}) \times (0.475 - 0.0126V + 0.240\sqrt{V})}$$

1-117E) $20^\circ\text{F} = 1.8(^\circ\text{C}) + 32$
 $-12 = 1.8C$
 -6.67°C

$40 = 1.8C + 32$
 $8 = 1.8C$
 4.44°C

$60 = 1.8C + 32$
 $28 = 1.8C$
 15.56°C



As the ambient temperature increases, the slope of the curve increases too.

THERMODYNAMICS I
FALL 2021

HOMEWORK #2 QUESTIONS

Energy, Energy Trans-fer, and General Energy Analysis

**Problems 2.15, 2.40, 2.45E, 2.50 , 2.56E, 2.67,
2.73, 2.91, 2.99, 2.122**

ABOVE AVERAGE

99%

Problem 2-15

A water jet that leaves a nozzle at 60 m/s at a flow rate of 120 kg/s is to be used to generate power by striking the buckets located on the perimeter of a wheel. Determine the power generation potential of this water jet.

Known: $\dot{m} = 120 \text{ kg/s}$, $V = 60 \text{ m/s}$

Find: The power generated by the water jet.

Schematic: None

Assumptions: Since the water strikes the bucket at a high speed and no height or elevation is mentioned. It is assumed that there is no potential energy. Also we assume that there is no density or pressure present. 10/10

Properties: All Properties needed are known.

Analysis: Equation:
$$P = (1/2) \cdot \dot{m} \cdot V^2$$
$$= (1/2)(120 \text{ kg/s})(60 \text{ m/s})$$
$$= 216000 \text{ W} \Rightarrow 216 \text{ kW}$$

Comments: ✓ 216 kW is the power generated by the water jet.

Problem 2-40

Water is being heated in a closed pan on top of a range while being stirred by a paddle wheel. During the process, 30 kJ of heat is transferred to the water, and 5 kJ of heat is lost to the surrounding air. The paddle-wheel work amounts to 500 N·m. Determine the final energy of the system if its initial energy is 12.5 kJ.

Known: $E(\text{in}) = 30 \text{ kJ}$, $E(\text{out}) = 5 \text{ kJ}$, $W(\text{in}) = 500 \text{ N}\cdot\text{m}$, $E(1) = 12.5 \text{ kJ}$

Find: Determine the final energy of the system.

Schematic:

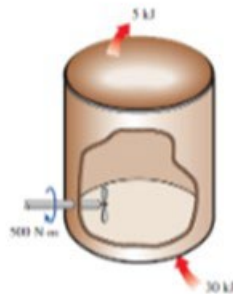


FIGURE P2-39

10/10

Assumptions: The work that is coming from the paddle is added work going into the pan.

Properties: All the properties are known.

Analysis: Equations: $E(\text{out}) - E(\text{in}) = E_2 - E_1$ $500 \text{ N}\cdot\text{m} \Rightarrow 0.5 \text{ kJ}$
 $(E(\text{out}) - E(\text{in})) + E_1 = E_2$
 $(30 \text{ kJ} + 0.5 \text{ kJ}) + 12.5 \text{ kJ} = E_2$
 $E_2 = 38 \text{ kJ}$

Comments: 38 kJ is the final energy of the system.

Problem 2-45E

A water pump increases the water pressure from 15 psia to 70 psia. Determine the power input required, in hp, to pump 0.8 ft³/s of water. Does the water temperature at the inlet have any significant effect on the required flow power?

Known: $P_1 = 15 \text{ psia}$, $P_2 = 70 \text{ psia}$, $\dot{V} = 0.8 \text{ ft}^3/\text{s}$,

Find: The power input required

Schematic: None

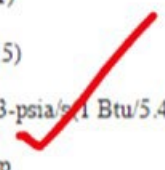
Assumptions: The increase in water pressure is the change in pressure. The question wants the answer in hp, so in the final answer must be convert to hp.

Properties: All Properties are present.

10/10

Analysis: Equation: $W = \dot{V}(P_2 - P_1)$

$$W = 0.8(70 - 15)$$

$$W = 44 \text{ ft}^3\text{-psia/s} (1 \text{ Btu} / 5.404 \text{ psia-ft}^3) (1 \text{ hp} / 0.7068 \text{ Btu})$$

$$= 11.5 \text{ hp}$$

Comments: Temperature was no given nor was it need to find the hp of the water pump.

Problem 2-50

Consider a 2100-kg car cruising at constant speed of 70 km/h. Now the car starts to pass another car by accelerating to 110 km/h in 5 s. Determine the additional power needed to achieve this acceleration. What would your answer be if the total mass of the car were only 700 kg?

Known: $m_1 = 2000 \text{ kg}$, $m_2 = 700 \text{ kg}$, $V_1 = 70 \text{ km/h}$, $V_2 = 110 \text{ km/h}$, $T = 5 \text{ s}$

Find: Determine the additional power needed to achieve the acceleration. And what would the total mass be if the car was only 700 kg.

Schematic: None

Assumptions: The problem wants to know the power the same car with two different masses, so there will be two different powers need to be shown.

Properties: All properties are presented

Analysis: Equation:

$$E = (m/2)(V_2 - V_1) \quad (70 \text{ km/h})(1000 \text{ m/1 km})(1 \text{ h/3600 s}) = 19.44 \text{ m/s}$$

$$= (2100/2)(30.56 - 19.44)$$

$$= 11666.67 \text{ W} \Rightarrow 11.7 \text{ kW}$$

$$(110 \text{ km/h})(1000 \text{ m/1 km})(1 \text{ h/3600 s}) = 30.56 \text{ m/s}$$

10/10

If $m = 700 \text{ kg}$

$$E = (700/2)(30.56 - 19.44)$$

$$= 3888.89 \text{ W}$$

$$= 3.9 \text{ kW}$$

Comments: The change in the mass affected the amount of energy or power to reach the accelerating speed.

Problem 2-56E

The steam requirements of a manufacturing facility are being met by a boiler whose rated heat input is 5.5×10^6 Btu/h. The combustion efficiency of the boiler is measured to be 0.7 by a handheld flue gas analyzer. After tuning up the boiler, the combustion efficiency rises to 0.8. The boiler operates 4200 h a year intermittently. Taking the unit cost of energy to be \$13/10⁶ Btu, determine the annual energy and cost savings as a result of tuning up the boiler.

Known: $n(1) = .7$, input = 5.5×10^6 Btu/h, $n(2) = .8$
 $T = 4200$ h yearly, \$13/10⁶ Btu

Find: Determine the annual energy and cost savings as a result of turning up the boiler.

Schematic: None

Assumptions: Since there will be two different outputs, we would have to take the difference in order to find the correct amount of savings.

Properties: Temperature

Analysis: Equation:

$$\begin{aligned} n_1 &= Q(\text{out})/Q(\text{in}) & n_2 &= Q(\text{out})/Q(\text{in}) \\ &= Q(\text{out}) = Q(\text{in}) \cdot n_1 & Q(\text{in}) &= Q(\text{out})/n_2 \\ &= (5.5 \times 10^6 \text{ Btu/h}) \cdot (.7) & Q(\text{in}) &= (3850000 \text{ Btu/h}) / (.8) \end{aligned}$$

$$Q(\text{out}) = 3850000 \text{ Btu/h} \quad Q(\text{in}) = 4.81 \times 10^6 \text{ Btu/h}$$

$$Q(\text{in}1) - Q(\text{in}2) = (5.5 \times 10^6) - (4.81 \times 10^6) \quad 10/10$$

$$E(\text{saved}) = 6.9 \times 10^5 \text{ Btu/h}$$

$$(\$13/10^6 \text{ Btu}) \cdot (4200 \text{ h/yr}) \cdot (6.9 \times 10^5) = \$37674$$

\$37674 per year

Comments: the annual amount saved would be \$ 37674 and the annual energy would be 6.9×10^5 Btu/h

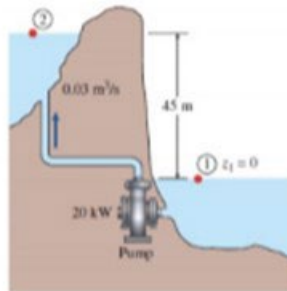
Problem 2-67

Water is pumped from a lower reservoir to a higher reservoir by a pump that provides 20 kW of shaft power. The free surface of the upper reservoir is 45 m higher than that of the lower reservoir. If the flow rate of water is measured to be 0.03 m³/s, determine mechanical power that is converted to thermal energy during this process due to frictional effects.

Known: $Z = 45\text{ m}$, $\dot{V} = 0.03\text{ m}^3/\text{s}$, $P(\text{shaft}) = 20\text{ kW}$

Find: Determine the mechanical power that is converted to thermal energy during this process due to frictional effects.

Schematic:



Assumptions: We can assume that there is no motion present or mentioned, we do not need to find the change in kinetic energy. There is no mass flow rate given so we have to use the volume flow rate to get the mass flow rate.

Properties: All properties are present.

Analysis: Equation: $P(\text{fric}) = P(\text{shaft}) - E(\text{mech})$

10/10

$$\dot{m} = (\text{density}) \cdot \dot{V}$$

$$= (1000)(0.03)$$

$$= 30\text{ kg/s}$$

$$E(\text{mech}) = \dot{m} \cdot gZ$$

$$= (30\text{ kg/s})(9.81\text{ m/s}^2)(45\text{ m})$$

$$= 13243.5\text{ W} \Rightarrow 13.2435\text{ kW}$$

$$P(\text{fric}) = 20\text{ kW} - 13.2435\text{ kW}$$
$$= 6.757\text{ kW}$$

Comments: The mechanical power produced is 6.757 kW

Problem 2-73

An oil pump is drawing 44 kW of electric power while pumping oil with $\rho = 860 \text{ kg/m}^3$ at a rate of $0.1 \text{ m}^3/\text{s}$. The inlet and outlet diameters of the pipe are 8 cm and 12 cm, respectively. If the pressure rise of oil in the pump is measured to be 500 kPa and the motor efficiency is 90 percent, determine the mechanical efficiency of the pump.

Known: $Z_1 = 8 \text{ cm}$, $Z_2 = 12 \text{ cm}$, Efficiency = 90%, $\dot{V} = 0.1 \text{ m}^3/\text{s}$,
 $W(\text{input}) = 44 \text{ kW}$, $P(\Delta) = 500 \text{ kPa}$

Find: Determine the mechanical efficiency of the pump.

Schematic:

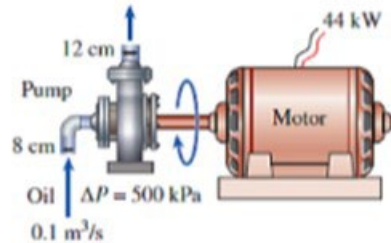


FIGURE P2-74

Assumptions: Even though there are lengths present there is no elevation with in the problem, so there is no potential energy present. Velocity is not given, but the flow rate and diameters are given in order to find velocity. There are two different diameters present so there will two velocities or in other words a change in velocity.

Properties: Pressure and Area.

10/10

Analysis:

Equation: For the Efficiency

$\eta = \text{Desired output} / \text{Required input}$

Solutions:

$$V_1 = \dot{V} / A_1 \quad A_1 = (\pi(r^2)) / 4$$

$$V_1 = 19.89 \text{ m/s}$$

$$V_2 = \dot{V} / A_2 \quad A_2 = (\pi(r^2)) / 4$$

$$V_2 = 8.84 \text{ m/s}$$

$$\text{pumphead}(h) = (P(\Delta)) / \text{density} + (V_2^2 - V_1^2) / 2 + g(Z_2 - Z_1)$$

$$= 43.077 \text{ m}$$

$$\text{Pump power}(P) = \rho g Q h$$

$$= 36.342 \text{ kW}$$

$$\eta = P / \text{pump input} \Rightarrow 36.342 \text{ kW} / (.09 * 44 \text{ kW}) \Rightarrow 91.77\%$$

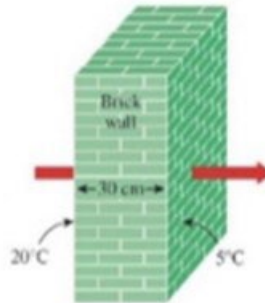
Problem 2-91

The inner and outer surfaces of a 5-m $\times$ 6-m brick wall of thickness 30 cm and thermal conductivity 0.69 W/m $\cdot$ °C are maintained at temperatures of 20°C and 5°C, respectively. Determine the rate of heat transfer through the wall, in W.

Known: $A = (5 \times 6) \text{ m}$, Thickness = 30 cm, $K = 0.69 \text{ W/m}\cdot^\circ\text{C}$, $T_2 = 20^\circ\text{C}$, $T_1 = 5^\circ\text{C}$

Find: Determine the rate of the heat transfer through the wall, in W.

Schematic:



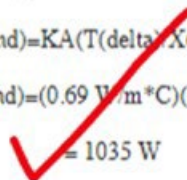
Assumptions: The problem is asking for heat energy moving in through the wall, so the answer will be in work energy form.

Properties: All properties are presented.

10/10

Analysis: Equation: $Q(\text{cond}) = KA(T(\text{delta})/X(\text{delta}))$

Solutions: $Q(\text{cond}) = (0.69 \text{ W/m}\cdot^\circ\text{C})(30 \text{ m}^2)(15^\circ\text{C}/.3\text{m})$

 = 1035 W

Comments: The rate of the transfer is 1035 W

Problem 2-99

A 9-cm-diameter spherical ball whose surface is maintained at a temperature of 110°C is suspended in the middle of a room at 20°C . If the convection heat transfer coefficient is $15\text{ W/m}^2\cdot^{\circ}\text{C}$ and the emissivity of the surface is 0.8 , determine the total rate of heat transfer from the ball.

Known: $h = 15\text{ W/m}^2\cdot^{\circ}\text{C}$, $T_s = (110 + 273)\text{ K}$, $T_f = (20 + 273)\text{ K}$, $D = 9\text{ cm}$

Find: The total rate of heat transfer from the ball.

Schematic: None

Assumptions: The question is asking for the total rate, so we have to find both the $Q(\text{rad})$ and $Q(\text{conv})$, and then add them together to get the total.

Properties: All properties are presented.

Analysis: Equation: $Q(\text{total}) = Q(\text{rad}) + Q(\text{conv})$ $q = \text{Boltzman constant}$, $E = \text{emissivity}$
 $A = \pi \cdot D^2$

Solution:

$$Q(\text{conv}) = hA(T_s - T_f)$$

$$Q(\text{conv}) = (15\text{ W/m}^2\cdot^{\circ}\text{C})(\pi(.09^2)\text{ m}^2)(110 - 20)^{\circ}\text{C}$$

$$= 34.35\text{ W}$$

10/10

$$Q(\text{rad}) = \epsilon \sigma A(T_s - T_f)^4$$

$$= (.8)(5.67 \times 10^{-8}\text{ W/m}^2\cdot^{\circ}\text{C})(.09^2)(383^4 - 293^4)$$

$$= 16.33\text{ W}$$

$$Q(\text{total}) = Q(\text{rad}) + Q(\text{conv})$$

$$= 16.33\text{ W} + 34.35\text{ W}$$

$$= 50.68\text{ W}$$

Comments: The area formula for the sphere was changed to fit the what the question was asking for.

Problem 2-122

Suppose a utility company is selling electric power for \$0.05/kWh at night and is willing to pay \$0.12/kWh for power produced during the day. Disregarding the frictional losses in piping and assuming the system operates for 10 h each in the pump and turbine modes during a typical day, determine the potential revenue this pump-turbine system can generate per year.

Known: $Z = 40 \text{ m}$, $\dot{V} = 2 \text{ m}^3/\text{s}$, $n = 0.75$

Find: Determine the potential revenue the pump-turbine system can generate per year.

Schematic:

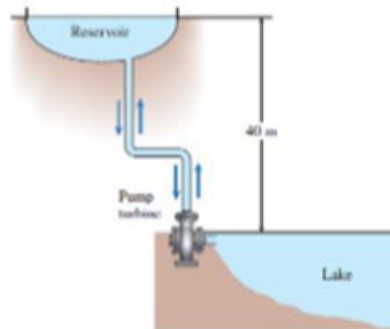


FIGURE P2-123

Assumption: It is asking for the mechanical energy power since there is no kinetic or internal energy, it is to be assumed that Kinetic and internal energy will not be needed.

Properties: No properties present.

Analysis:

Equations: $W(\text{pump}) = E(\text{mech})/n$ $W(\text{Turbine}) = n(\text{gen}) * E(\text{mech})$

9/10

Solutions: $E(\text{mech}) = \dot{m} * P(\text{delta})$
 $= \dot{m} * g * Z$
 $= (2000 \text{ kg/s}) * (9.8 \text{ m/s}^2) * (40 \text{ m})$
 $= 784000 \text{ W} \Rightarrow 784 \text{ kW}$

$\dot{m} = \text{density} * \dot{V}$
 $= (1000 \text{ kg/m}^3) * (2 \text{ m}^3/\text{s})$

$W(\text{turbine}) = (0.75) * (784)$
 $= 588 \text{ kW}$

$\text{Pay} = (0.03 \text{ kWh}) * (10 \text{ h}) * (365) * (1045.3)$
 $= \$114460.35$

$W(\text{pump}) = E(\text{mech})/n(\text{motor})$
 $= 784 \text{ kW} / 0.75$
 $= 1045.3 \text{ kW}$

$\text{Receive} = (0.08 \text{ kWh}) * (10 \text{ h}) * (365) * (1045.3)$
 $= \$171696$

$\text{Profit} = \$171696 - \114460.35
 $= \$57235.70$

off

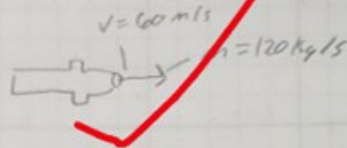
AVERAGE

Statement: A water jet that leaves a nozzle at 60 m/s at a flow rate of 120 kg/s is to be used to generate power by striking the buckets located on the perimeter of a wheel. Determine the power generation potential of this water jet.

Known: Velocity, 60 m/s; Mass flow rate of water, 120 kg/s

Find: Power generation, E_{mech}

Schematic:



Assumption: Mechanical energy of a flowing fluid can be expressed as a unit mass base.

Properties: all are known

Analysis:

$$e_{mech} = \frac{P}{\rho} + \frac{V^2}{2} + gz$$

$$E_{mech} = \dot{m} e_{mech}$$

$$E_{mech} = \dot{m} \left(\frac{P}{\rho} + \frac{V^2}{2} + gz \right)$$

$$E_{mech} = 120 \cdot \left(\frac{60^2}{2} \right) \text{ J/s}$$

$$= \frac{216000 \text{ J/s}}{1000}$$

$$= 216 \text{ kW}$$

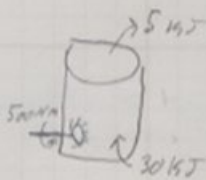
$$\boxed{E_{mech} = 216 \text{ kW}}$$

Statement: Water is being heated in a closed pan on top of a range while being stirred by a paddle wheel. During the process, 30 kJ of heat is transferred to the water, and 5 kJ of heat is lost to the surrounding air. The paddle-wheel work amounts to 500 N·m. Determine the final energy of the system if its initial energy is 12.5 kJ.

Known: Energy in: 30 kJ, 500 N·m; Energy out: 5 kJ;
Initial Energy: 12.5 kJ

Find: Final energy

Schematic:



Assumption: None

Properties: Initial energy, 12.5 kJ

Analysis: $E_{in} - E_{out} = E = E_2 - E_1$

$$W = -500 \text{ J} \\ = -0.5 \text{ kJ}$$

$$30 + (-5) = 25$$

10/10

$$E = W + \Delta E$$

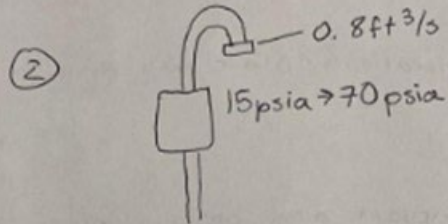
$$25 = -0.5 + (E_2 - 12.5)$$

$$25.5 = E_2 - 12.5$$

$$E_2 = 38 \text{ kJ}$$

2.45 E

- ① Water pump increases water pressure from 15 psia to 70. Find Hp needed to pump 0.8 ft³/s of water.



- ③ Hp required $\approx 10-13$ Hp

④

$$\frac{\text{ft}^3 \cdot \text{psia}}{\text{s}} \left(\frac{1 \text{ Btu}}{5.404 \text{ psia} \cdot \text{ft}^3} \right) \left(\frac{1 \text{ hp}}{0.7068 \text{ Btu/s}} \right)$$
$$W = V(P_2 - P_1)$$

- ⑤ psia to Hp conversion

⑥

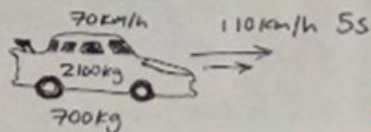
$$(0.8)(70 \text{ psia} - 15 \text{ psia}) = 44 \frac{\text{ft}^3 \cdot \text{psia}}{\text{s}} \quad \text{10/10}$$
$$44 \left(\frac{1 \text{ Btu}}{5.404 \text{ psia} \cdot \text{ft}^3} \right) \left(\frac{1 \text{ hp}}{0.7068 \text{ Btu/s}} \right) = \boxed{11.5 \text{ hp}}$$

- ⑦ 11.5 hp is required to pump 0.8 ft³/s of water.
There is no effect on the water flow or power due to the water temperature.

2-50

- ① 2100-kg car going at constant speed of 70 km/h. Car accelerates to 110 km/h in 5 seconds. Determine the additional power needed to accelerate. Answer if car mass = 700 kg.

②



10/10

- ③ Power in kW ≈ 120 kW at 700 kg ≈ 60 kW

④ $x \text{ km/h} = \frac{x}{3.6} \text{ m/s}$ $\Delta KE = \frac{1}{2} m (V_2^2 - V_1^2)$ Power = $\frac{\Delta KE}{t}$

⑤ $70 \text{ km/s} = 19.44 \text{ m/s}$ $110 \text{ km/h} = 30.56 \text{ m/s}$

⑥ $\Delta KE = \frac{1}{2} (2100 \text{ kg}) (30.56 \text{ m/s})^2 - (19.44 \text{ m/s})^2 = 583800 \text{ J}$
 $P = \frac{583800 \text{ J}}{5 \text{ s}} = \boxed{117 \text{ kW}} \frac{2100 \text{ kg}}{\text{kg}} \quad 117 \text{ kW} / 3 = \boxed{39 \text{ kW}} \frac{700 \text{ kg}}{\text{kg}}$

- ⑦ The additional power needed to accelerate to 110 km/h in 5 s is $117 \frac{\text{kW}}{\text{kg}}$ and at 700 kg the car is $\frac{1}{3}$ the original mass so the power would also be $\frac{1}{3}$ which is 39 kW.

Statement: The steam requirements of a manufacturing facility are being met by a boiler whose rated heat input is $5.5 \times 10^6 \text{ Btu/h}$. The combustion efficiency of a boiler is measured to be 0.7. After tuning up the boiler, the combustion efficiency rises to 0.8. The boiler operates 4200 hours a year. Unit cost is $\$13/10^6 \text{ Btu}$. Determine the annual energy and cost savings as a result of tuning up the boiler.

Known: heat in: $5.5 \times 10^6 \text{ Btu/h}$; boiler tuning A = 0.7;
boiler tuning B, 0.8; hours: 4200; cost: $13/10^6 \text{ Btu}$

Find: annual energy saving cost.

Schematic: None

Assumption: The savings would equal the energy cost times rate of savings times how long it runs.

Properties: all are known

Analysis: $\eta_1 = \frac{\dot{Q}_{out}}{\dot{Q}_{in,1}}$ $\eta_2 = \frac{\dot{Q}_{out}}{\dot{Q}_{in,2}}$

$$0.7 = \frac{\dot{Q}_{out}}{5.5 \times 10^6}$$

$$\dot{Q}_{out} = 3.85 \times 10^6 \text{ Btu/h}$$

$$0.8 = \frac{3.85 \times 10^6}{\dot{Q}_{in,2}}$$

$$\dot{Q}_{in,2} = 4.81 \times 10^6 \text{ Btu/h}$$

$$\dot{Q}_{save} = \dot{Q}_{in,1} - \dot{Q}_{in,2}$$

$$\text{Saving} = (\$) \cdot (h) \cdot (\dot{Q}_{save})$$

$$\dot{Q}_{save} = (5.5 \times 10^6) - (4.81 \times 10^6)$$

$$\dot{Q}_{save} = 0.69 \times 10^6 \text{ Btu/h}$$

$$\text{Saving} = \left(\frac{13}{10^6 \text{ Btu}} \right) \times (4200 \text{ h/yr}) \times (0.69 \times 10^6)$$

$$\text{Saving} = \$37,674 \text{ annually}$$

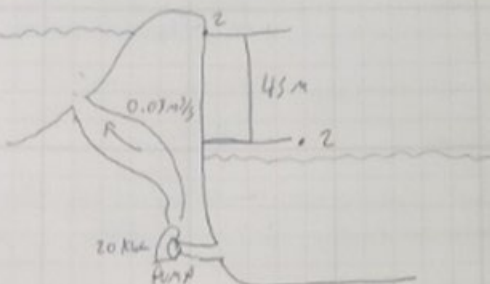
Problem 2-67

Statement: Water is pumped from a lower reservoir to a higher one by a pump that provides 20 kW. The surface is 45 m higher than the lower. If the flow rate is $0.03 \text{ m}^3/\text{s}$, Determine mechanical power that is converted to thermal energy during this process.

Known: height: 45 m; Flow rate: $0.03 \text{ m}^3/\text{s}$; $P_{\text{actual}} = 20 \text{ kW}$

Find: Power lost

Schematic:



Assumption: initial height is zero

Properties: all are known

Analysis:

$$P_{\text{actual}} = 20 \text{ kW}$$

$$h = 45 \text{ m}$$

$$\dot{V} = 0.03 \text{ m}^3/\text{s}$$

$$P_{\text{lost}} = P_{\text{actual}} - P_{\text{ideal}}$$

$$e = g \cdot h$$

$$\dot{m} = \dot{V} \cdot \rho$$

$$P_{\text{ideal}} = \dot{m} \cdot e$$

10/10

$$e = 9.81 \times 45$$

$$= 441.45 \text{ J/kg}$$

$$\dot{m} = 0.03 \text{ m}^3/\text{s} \times 1000 \text{ kg/m}^3$$

$$= 30 \text{ kg/s}$$

$$P_{\text{ideal}} = 441.45 \text{ J/kg} \times 30 \text{ kg/s}$$

$$= 13,243.5 \text{ W}$$

$$= 13.24 \text{ kW}$$

$$P_{\text{lost}} = 20 \text{ kW} - 13.24 \text{ kW}$$

$$P_{\text{lost}} = 6.76 \text{ kW}$$

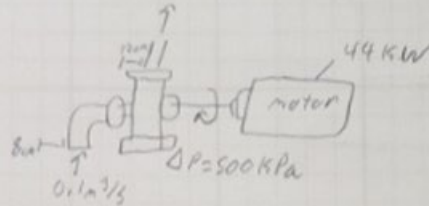
Problem 2-73

Statement: oil pump is drawing 44 kW of electric power while pumping while pumping oil with $\rho = 860 \text{ kg/m}^3$ at a rate of $0.1 \text{ m}^3/\text{s}$. The inlet and outlet diameter of the pipe is 8 cm and 12 cm. If the pressure rise of oil in the pump is measured to be 500 kPa and the motor efficiency is 90%, determine the mechanical efficiency of the pump.

Known: Power in = 44 kW; inlet diameter = 8 cm; outlet diameter = 12 cm; $\Delta P = 500 \text{ kPa}$; flow rate = $0.1 \text{ m}^3/\text{s}$; efficiency = 90%; $\rho = 860 \text{ kg/m}^3$

Find: Mechanical efficiency of the pump

Schematic:



Assumption: none

Properties: all are known

Analysis:

$P_{in} = 44 \text{ kW}$
 $\rho = 860 \text{ kg/m}^3$
 inlet = 8 cm
 outlet = 12 cm
 $\Delta P = 500 \text{ kPa}$
 $\dot{V} = 0.1 \text{ m}^3/\text{s}$
 $\eta_m = 90\%$

$$\Delta e = \frac{P_2 - P_1}{\rho} + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)$$

$$V_1 = \frac{\dot{V}}{A_1} = \frac{0.1}{\frac{\pi}{4} \times 0.08^2} = 19.894 \text{ m/s} \quad \dot{V}_{dot} = V \times A$$

$$V_2 = \frac{\dot{V}}{A_2} = \frac{0.1}{\frac{\pi}{4} \times 0.12^2} = 8.84 \text{ m/s}$$

$$\Delta e = \frac{500 \times 10^3}{860} + \frac{8.84^2 - 19.894^2}{2} = 422.58 \text{ J/kg}$$

$$\dot{m} = \dot{V} \times \rho$$

$$\dot{m} = 860 \times 0.1 = 86 \text{ kg/s}$$

$$P_{out} = \dot{m} \times \Delta e = 86 \times 422.58 = 36342.88 \text{ W}$$

$$P_{out} = 36.34288 \text{ kW}$$

$$\eta_{mech} = \frac{P_{out}}{P_{in} \times \eta_m} = \frac{36.34188}{44 \times 0.9}$$

$$\eta_{mech} = 91.77\%$$

Homework 2

2-92

Statement A 9-cm-diameter ball whose surface is maintained at a temperature of 110°C is suspended in the middle of a room at 20°C . If the convection heat transfer is $15\text{ W/m}^2\cdot^\circ\text{C}$ and the emissivity of the surface is 0.8 , determine the total rate of heat transfer from the ball.

Known ball diameter, T_{surf} , surface temp, 110°C ; room temp, 20°C
Coefficient, $15\text{ W/m}^2\cdot^\circ\text{C}$; emissivity

Find Total rate of heat transfer

Assumption The amount of total heat transfer will be based on the convection heat transfer

Properties Need the surface area and the radiation heat transfer 10/10

analysis

$$A = \pi(0.09)^2 \quad \text{①} \quad \dot{Q}_{\text{conv}} = 15(0.0259)(110-20) \quad \text{②}$$

$$A = 0.0259\text{ m}^2 \quad \dot{Q}_{\text{conv}} = 71.29\text{ W}$$

$$\dot{Q}_{\text{rad}} = 0.8(0.0259)(5.67 \times 10^{-8})((110+273)^4 - (20+273)^4)$$

$$\dot{Q}_{\text{rad}} = 16.3\text{ W}$$

$$\dot{Q}_{\text{total}} = 50.59\text{ W}$$

Homework 2

2-122

Statement

The overall efficiency of the turbine-generator is 84%.
Disregarding frictional losses in piping, estimate the electric power output of this plant.

Known

65 m³/s of water; 90 m elevation; overall efficiency, 84%

Find

Electric power output

Schematic



Assumption

The density of water is 1000 kg/m³

Properties

Use ρ , η , & $\dot{W}_{max}$

analysis

$$\eta_{turb} = 0.84(90)\left(\frac{1}{1000}\right) = 0.8829 \text{ kJ/kg}$$

incomplete

$$\dot{m} = 1000(65) = 65,000 \text{ kg/s}$$

$$\dot{W}_{max} = 65,000(0.8829)\left(\frac{1}{1000}\right) = 57.39 \text{ MW}$$

$$\dot{W}_{elec} = 0.84(57.39) = \boxed{48.2 \text{ MW}}$$

BELOW AVERAGE

Summer Brendon

HWA 2

09/24/21

215 A water jet that leaves a nozzle at 60 m/s at a flow rate of 120 kg/s is to be used to generate power by striking the buckets located on the perimeter of a wheel. Determine the power generation potential of this water jet.

Known: $V = 60 \text{ m/s}$, $m = 120 \text{ kg/s}$

Find: Determine the power generation potential of this water jet.

Schematics: N/A

10/10

Assumptions: The flow energy, P_f will not be a huge factor in solving this problem.

Properties: The flow of the water jet is identified as the kinetic energy. Power generation is unknown.

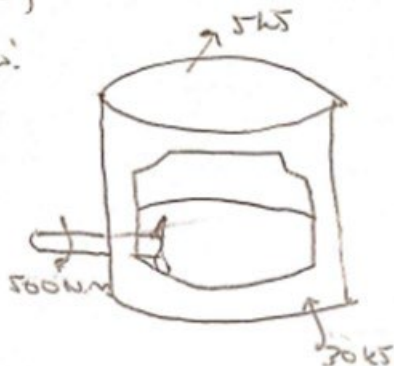
Analysis: $E = m(V^2/2) = 120(60^2/2)(1/1000) = 216 \text{ kW}$

270 Water is being heated in a closed pan on top of a range with a paddle stirred by a paddle wheel. During the process, 30 kJ of heat is transferred to the water and 7 kJ of heat is lost to the surrounding air. The paddle wheel work amounts to 500 N·m. Determine the final energy of the system if its initial energy is 12.5 kJ.

Known: $E_{in} = 30 \text{ kJ}$, $E_{out} = 7 \text{ kJ}$, $W = 500 \text{ N}\cdot\text{m}$, $E_1 = 12.5$

Find: Determine the final energy of the system if its initial energy is 12.5 kJ.

Schematic:



Assumptions: We will use the simple total energy equation which is $E_{in} - E_{out} = \Delta E = E_2 - E_1$.

Properties: The initial energy is known, as well as the energy leaving and entering. The work is known while the final energy is unknown. 10/10

Analysis: $E_{in} - E_{out} = \Delta E$
 $= 30 - 7 = -500 \left(\frac{1}{1000} \right) + E_2 - 12.5$
 $= 38 \text{ kJ}$

2-45E A water pump increases the water pressure from 15 psia to 70 psia. Determine the power input required in hp, to pump 0.8 ft³/s of water. Does the water temperature at the inlet have any significant effect on the required flow power?

Known: $P_1 = 15$, $P_2 = 70$, $Q = 0.8$

Find: Does the water temperature at the inlet have any significant effect on the required flow power?

Schematic: N/A

Assumptions: The unit "psia" will be converted to "hp."

Properties: The initial and final pressure values are known as well as the ~~flow~~ velocity. Power input is unknown.

Analysis: $W = Q(P_2 - P_1) = (0.8)(70 - 15) = 44 \text{ psia}$ 10/10

Convert to hp = $44 \frac{\text{ft}^3}{\text{s}} \text{ psia} \approx 1 \frac{\text{Btu}}{5.404 \text{ psia ft}^3} \left(\frac{1 \text{ hp}}{0.7068 \text{ Btu/s}} \right)$

$\approx 11.5 \text{ hp}$

2-50 Consider a stocky car cruising at a constant speed of 70 km/h. Now the car starts to pass another car by accelerating to 110 km/h in 5 s. Determine the additional power needed to achieve this acceleration. What would your answer be if the total mass of the car were only 700 kg?

Known: $v_1 = 70 \frac{\text{km}}{\text{h}}$, $v_2 = 110 \frac{\text{km}}{\text{h}}$, $t = 5 \text{ s}$, $m_s = 2100 \text{ kg}$, $m_p = 700 \text{ kg}$

Find: Determine the additional power needed to achieve this acceleration. What would your answer be if the total mass of the car were only 700 kg?

Schematic: N/A

Assumptions: Several ~~assessments~~ conversions are going to be made as well as two different potential values

10/10

Properties: Two forms of velocity and mass are known throughout the problem while the desired kinetic energy is unknown

Analysis: $KE_s = \frac{1}{2} m v^2 = \frac{1}{2} (2100) \left(70 \frac{\text{km}}{\text{h}} \right) \left(\frac{1000}{3600} \left(\frac{\text{m}}{\text{s}} \right) \right)^2$
 $= 354,930 \left(\frac{1}{1000} \right) = 354.93 \text{ kJ}$

$KE_p = \frac{1}{2} m v^2 = \frac{1}{2} (700) \left(110 \right) \left(\frac{1000}{3600} \left(\frac{\text{m}}{\text{s}} \right) \right)^2$
 $= 590.33 \text{ kJ}$

$D = \frac{KE_p - KE_s}{t} = \frac{590.33 - 354.93}{5} = 46.68 \text{ kW}$

d-50 ContinuedAnalysis: $m = 700 \text{ kg}$

$$KE_i = \frac{1}{2} m v_i^2 = \frac{1}{2} (700) \left((70) \left(\frac{1000}{3600} \right) \left(\frac{1}{\text{km/hr}} \right) \right)^2$$
$$= 132,330 \left(\frac{1}{1000} \right) = 132.33 \text{ kJ}$$

$$KE_f = \frac{1}{2} m v_f^2 = \frac{1}{2} (700) \left((110) \left(\frac{1000}{3600} \right) \left(\frac{1}{\text{km/hr}} \right) \right)^2$$
$$= 326.775 \text{ kJ}$$

$$P = \frac{326.775 - 132.33}{5} = 38.9 \text{ kW}$$

PROBLEM: 2.56E

KNOWN: HEAT INPUT, $W_{HP} = 5.5 \times 10^6$ Btu/h

INT. COMBUSTION EFFICIENCY, $\eta_i = 0.7$, STEAM OUTPUT, W_{OP}

TIME = 4200 HOURS, COST OF ENERGY \$13/10⁶ Btu

FINAL COMBUSTION EFFICIENCY: $\eta_f = 0.8$

FIND: STEAM OUTPUT, W_{OP} AND

TOTAL COST, $\$C_{TOTAL}$

SAVINGS COST, AS WELL

SCHEMATICS: N/A

ASSUMPTIONS: N/A

ANALYSIS: $W_{OP} = W_{HP} \times \eta_i$

$C_{TOTAL} = \$C \times W_{OP} \times t$

SOLUTION: FIND STEAM OUTPUT, THEN USE TO FIND THE TOTAL COST.

$$(0.7) W_{OP} = W_{HP} \times \eta_i = 5.5 \times 10^6 \text{ Btu/h} \times 0.7 \\ = 3.85 \times 10^6 \text{ Btu/h}$$

$$C_{TOTAL} = C \times W_{OP} \times t$$

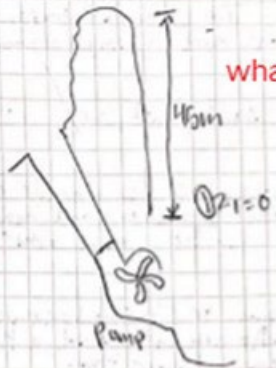
$$= \$13/10^6 \text{ Btu} \times 3.85 \times 10^6 \text{ Btu/h} \times 4200 \text{ h} \\ = \$210,210$$

$$(0.8) W_{OP} = W_{HP} \times \eta_f = 5.5 \times 10^6 \text{ Btu/h} \times 0.8 = 4.4 \times 10^6$$

$$C_{TOTAL} = C \times W_{OP} \times t = \$13/10^6 \text{ Btu} \times 4.4 \times 10^6 \text{ Btu/h} \times 4200 \text{ h} = 240,240$$

$$SAVE = 240,240 - 210,210 = \$30,030$$

Jeremy Baines, | Homework #2 | 9/25/2021



Calculate mass flow rate

$$\dot{m} = \rho AV$$

$$= \rho V \text{ kg/s}$$

$$m = 100 \times 0.03$$

$$= 30 \text{ kg/s}$$

Calculate change in specific potential energy

$$\Delta p_e = gh$$

$$\Delta p_e = 9.85 \times 45$$

$$= 441 \text{ m}^2/\text{s}^2$$

Calculate mechanical power converted to thermal energy during friction

$$\dot{W}_{\text{fric}} = \dot{W}_{\text{shaft}} - \dot{E}_{\text{mech}}$$

$$\dot{W}_{\text{fric}} = (26 - 19.25)$$

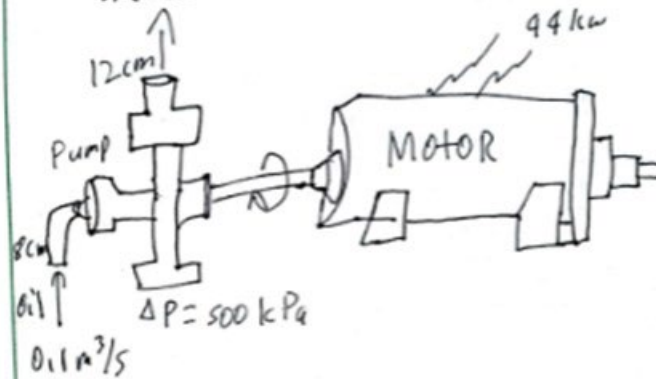
$$= 6.75 \text{ kW}$$

2.73

known: oil pump draws - 44 kW
pumping oil - $\rho = 960 \text{ kg/m}^3$
rate = $0.1 \text{ m}^3/\text{s}$
inlet and outlet = 8 cm and 12 cm
pressure - 500 kPa
motor efficiency - 90 percent

Find: mechanical efficiency of the pump

Schematic:



Assumptions:

The pump is gonna require kinetic energy and velocity.

Properties:
rpm: 15 rpm

Power output: 180 kW

mass flow rate: 42,000 kg/s density air: 1.31 kg/m³

tip velocity = 250 km/h

Analysis: $C 1 \frac{\text{km}}{\text{h}} = \frac{5}{18} \text{ m/s}$

$m = \rho A V \text{ kg/s}$ - mass flow rate

$V_{\text{tip}} = \frac{\pi d N}{60} \text{ m/s}$ - velocity

$V = \frac{m}{\rho A} \text{ m/s}$ - Average Velocity
of wind turbine

$\eta_{\text{turbine}} = \frac{W_{\text{out}}}{W_{\text{in}}} = \frac{7}{10}$ - conversion efficiency
turbine

$$\text{Diameter} = \frac{250 \times \left(\frac{5}{18}\right) \times 60}{\pi (15)}$$

$$= 98.42 \text{ m}$$

Average velocity:

$$\frac{42,000}{(1.31) \left(\frac{\pi}{4} \times (98.42)^2\right)}$$

$$V = 5.22 \text{ m/s}$$

kinetic energy:

$$W_{ke} = \frac{1}{2} m v^2$$

$$= \frac{1}{2} \times 42,000 \times (5.22)^2$$

$$= 572.2 \text{ kW}$$

$$\text{efficiency} = \frac{180}{572.2}$$

$$= 0.3145$$

mechanical
efficiency = 31.45%

2.91

known:

inner and outer surfaces - $5\text{m} \times 6\text{m}$ brick wall

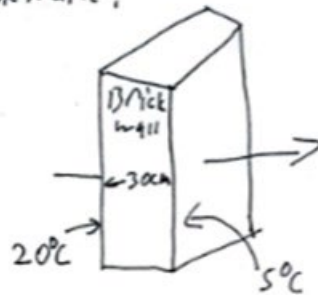
thickness - 30cm

thermal conductivity - 0.69 W/m

maintained temperature - 20°C and 5°C

Find: Determine the rate of heat transfer through the wall.

Schematic:



Assumptions:

In order to determine the heat transfer ~~by~~ ~~Need first to~~ you need to determine the size, area, and ~~with~~ thickness of the brick wall.

properties:

Area of the wall

$$A = 5 \times 6 = 30 \text{ m}^2$$

Thickness = $L = 30 \text{ cm}$
 0.3 m

10/10

Thermal conductivity: $k = 0.69 \text{ W/m}^\circ\text{C}$

Temperature difference: $\Delta T = 20 - 5 = 15^\circ\text{C}$

Analysis

Q rate of heat: $k \frac{\Delta T}{L}$

$$= 0.69 \times 30 \times \left(\frac{15}{0.3}\right)$$

$$= \boxed{1035 \text{ W}}$$

2.44

known:

spherical ball - 9cm diameter

temperature - 110°C

middle of a room - 20°C

heat transfer coefficient - $15 \text{ W/m}^2\text{C}$

emissivity of surface - 0.8

Find: Determine the total rate of heat transfer from the ball.

schematic: None

Assumptions:

To find the rate of heat transfer you have to use all the three heat transfers which is conduction, convection, or radiation.

Properties:

Diameter: $D = 9 \text{ cm} = 0.09 \text{ m}$

Surface temperature of the ball - 110°C

Room temperature = 20°C

Convection heat transfer coefficient - $15 \text{ W/m}^2\text{C}$

Emissivity of surface = 0.8

10/10

Analysis:

Heat transfer surface area: $A = \pi D^2$

$$A = 3.14 \times (0.09)^2$$

$$A = 0.0254 \text{ m}^2$$

convection heat transfer

$$Q_{\text{conv}} = (15) \times 0.10254 \times (110 - 20) \\ = 39.29 \text{ W}$$

convection radiation

$$Q_{\text{rad}} = 0.8 \times 0.10254 \times 5.67 \times 10^{-8} \left[(110 + 273)^4 - (20 + 273)^4 \right] \\ = 16.3 \text{ W}$$

$$Q_{\text{conv}} + Q_{\text{rad}} = Q_{\text{total}}$$

$$39.29 + 16.3 = 55.59 \text{ W}$$

Given:

$$\text{Electrical Power cost} = \$0.05/\text{kWh}$$

Question #2.12

$$\text{Power Produced} = 90.12/\text{kWh}$$

$$\text{Large reservoir level} = 40 \text{ m}$$

 $\Rightarrow$ Calculate work done by turbine

$$\text{Work (turbine)} = m \Delta p$$

$$= \rho V g \Delta x$$

$$= 1000 \times 2 \times 9.8 \times 40$$

$$(V)_{\text{turbine}} = 784 \text{ kW}$$

Power required to pump water from lower to high reservoir
in 784 kW $\rightarrow$ W turbine

$$= 0.75 \times 784$$

Actual pump
power

$$W_{\text{turb}} = 588$$

$$W_{\text{pump}} = 784 / 0.75 = 1045.33 \text{ kW}$$

 $\Rightarrow$ Cost per year for pump

$$\text{Cost} = (W_{\text{pump}}) \times \Delta t \times \text{Cost of unit}$$

$$(1045.33)(365 \times 10) 0.05$$

$$\text{Cost} = 19072.725 / \text{yr}$$

 $\Rightarrow$ Revenue of Turbine per year

$$W_{\text{turbine}} \times \Delta t \times \text{Cost of unit}$$

$$= 588 \times (365 \times 10 / \text{yr}) \times 0.12$$

$$\rightarrow 257,544 / \text{yr}$$

⇒ Net income of turbine system

$$\text{Net income} = \text{Revenue} - \text{Cost}$$

$$= 257544 - 190772.725$$

$$= 66771.275$$

$$\boxed{\text{Net income} = 66771.275}$$

THERMODYNAMICS I
FALL 2021

HOMEWORK 3

TOPICS COVERED IN HOMEWORK 3

Properties of Pure Substances

HOMEWORK #3 QUESTIONS

Problems 3.25, 3.26E, 3.51, 3.64, 3.75, 3.84, 3.100, 3.121, 3.131

ABOVE AVERAGE

\$2.25

Known:

$$\begin{aligned} T^* &= 140, 150 \\ P, \text{ kPa} &= 200, 500, 800, 2000 \\ h, \text{ kJ/kg} &= 1100, 3163.2 \\ x &= 0.7, 0.0 \end{aligned}$$

Find: Complete this table for H_2O

State	T^*, C	$P, \text{ kPa}$	$h, \text{ kJ/kg}$	x	Phase description
1	140	200	1100	0.7	
2	150	500		0.0	
3	800		3163.2		

Assumptions: The property tables for water will be needed to complete the following table.

Properties: You must use the water tables and the equation for h , $h = h_f + xh_{fg}$

Analysis:

T^*, C	$P, \text{ kPa}$	$h, \text{ kJ/kg}$	x	Phase description
140.21	200	2045.83	0.7	Saturated vapor
150	361.53	1300	0.75	Saturated vapor
171.66	900	752.74	0.0	Saturated liquid
80	500	335.03	—	Compressed liquid
350	800	3163.2	—	Superheated vapor

Use table at $P = 0.30 \text{ MPa}$

11

200 kPa

$$\begin{aligned} h &= h_f + xh_{fg} \\ &= 104.7 + (0.7)(2045.83) = 2045.83 \end{aligned}$$

#2 361.53 kPa

$$h_f + xh_{fg} = 0$$

$$1300 = 752.74 + x(2045.83) = 0.3163$$

3163.2 > 2045.83

#3 900 kPa

$$\begin{aligned} h &= h_f + xh_{fg} \\ &= 752.74 + (0.7)(2045.83) = 2045.83 \end{aligned}$$

#4 800 kPa

$$T_s = 171.66$$

$$h_f = 335.03$$

$$h_g = h$$

3.26E

Known: $T, ^\circ F: 15, 10, 110$
 $P, \text{psia}: 30, 70, 120$
 $h, \text{Btu/lbm}: 78, 129.46$
 $x: 0.6, 1.0$

Find: Complete this table for refrigerant-134a

Schematic:

$T, ^\circ F$	P, psia	$h, \text{Btu/lbm}$	x	Phase description
15	30	78	0.6	
10	70			
110	120	129.46	1.0	

Assumptions: The property tables for refrigerants will be needed to complete the following table.

Properties: You must use the refrigerant tables and the equation for h , $x = h_{\text{liq}}/h_{\text{g}}$

Analysis:

$T, ^\circ F$	P, psia	$h, \text{Btu/lbm}$	x	Phase description
65.84	30	78	0.6	Vapor
15	29.759	78	0.6	Vapor
10	70		—	Compressed liquid
110	120	129.46	—	Compressed liquid
110	117.35	117.35	1.0	Saturated Vapor

#1 30 psia

$$x = h_{\text{liq}}/h_{\text{g}} = 78 - 73.591 / 78.736 - 0.56$$

10/10

#2 15 °F

$$x = h_{\text{liq}}/h_{\text{g}} = 0.6 = h - 16.879 / 13.603 = 69.92$$

#3 110 °C

$$h_{\text{g}} = 117.35$$

#3 120 psia

 $n > h_{\text{g}}$

$$129.46 > 117.35 > 31.304 \text{ — Saturated} \\ = 116.25$$

Noah Smith

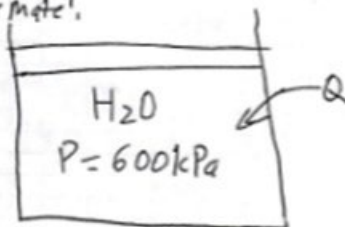
~~3.11~~ 3.51

known
A piston-cylinder device - 0.005 m^3 liquid
water vapor - 0.9 m^3
equilibrium - 600 kPa
temperature - 200°C

Find

- What is the initial temperature of the water?
- Determine the total mass of the water.
- Calculate the final volume
- Show the process on a P-V diagram with respect to saturation lines.

Schematic:



Assumptions:

Equations:

a, 159.8°C

$$b_1 \quad m_f = \frac{V_{f, \text{in}}}{V_f}$$

$$m_f = \frac{0,005}{0,0011}$$

$$m_f = 4,545 \text{ kg}$$

$$m_g = \frac{V_g}{V_g}$$

$$= \frac{0,9}{0,3158}$$

$$= 2,849 \text{ kg}$$

$$m_t = m_f + m_g$$

$$m_t = 4,545 + 2,849$$

$$= 7,394 \text{ kg}$$

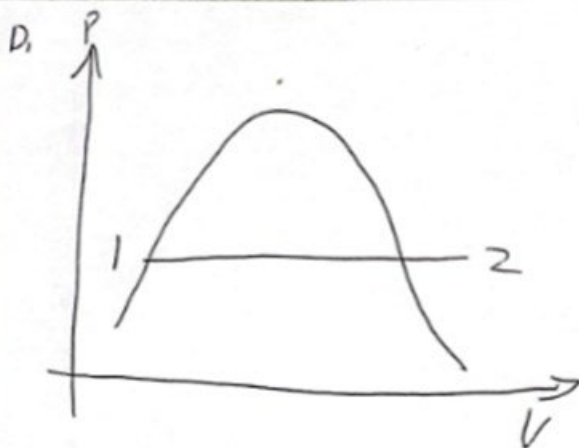
10/10

$$c_1 \quad P_2 = P_1 = 600 \text{ kPa}$$

$$V_2 = m_t \times V_2$$

$$V_2 = 7,394 \times 0,352$$

$$V_2 = 2,6026 \text{ m}^3$$



Conclusion:

Therefore, the required process is represented
On Saturation lines

3.64

Known:

Steam - 3.5 MPa

Superheated - 50°C

Cooling - 200°C

Find:

a. ~~initial~~ initial temperature

b. the enthalpy change per unit mass of the steam by the time the piston first hits the stops.

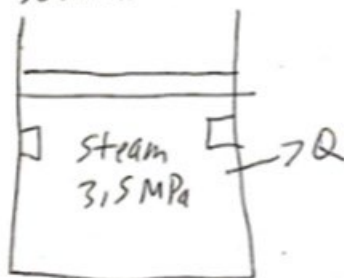
c. The final pressure and the quality.

Equation:

$P_1 = 3.5 \text{ MPa}$ ~~superheat~~ superheat - 50°C

$T_{\text{sat}} = 242.55^\circ\text{C}$

Schematic:



Solution 11

$$T_1 = 242,55 + 5$$

$$= 247,55^\circ\text{C} \quad \text{use table}$$

$$P_1 = 3,5 \text{ MPa}$$

$$h_1 = 2821,1 \text{ kJ/kg}$$

$$P_2 = P_1 = 3,5 \text{ MPa} \quad x_2 = 0$$

$$h_2 = 1049,7 \text{ kJ/kg}$$

$$\Delta h = h_2 - h_1$$

$$\Delta h = 1049,7 - 2821,1$$

$$\Delta h = -1771,4 \text{ kJ/kg}$$

$$T_3 = 200^\circ\text{C} \quad 10/10$$

$$V_3 = V_2 = 0,001235 \text{ m}^3/\text{kg}$$

$$P_3 = 1555 \text{ kPa}$$

$$x_3 = 0,0006$$

Noah Smith

3.75

known:

1 - m³ tank - air - $T_1 = 10^\circ\text{C}$ - $P_1 = 350\text{ kPa}$

another tank - 3 kg - $T_2 = 35^\circ\text{C}$ - $P_2 = 200\text{ kPa}$

Thermal equilibrium - 20°C

R : constant - 0.287 kPa

Find:

Determine the volume of the second tank and the final equilibrium pressure of air

~~Schematic:~~

Assumptions

Equations:

$$m_1 = \frac{P_1 V_1}{RT_1}$$

$$= \frac{(350\text{ kPa})(1\text{ m}^3)}{(0.287\text{ kPa})(10^\circ\text{C} + 273)}$$

$$= 4.1709\text{ kg}$$

$$V_2 = \frac{m_2 RT_2}{P_2}$$

$$= \frac{(3\text{ kg})(0.287\text{ kPa})(273 + 35)}{200\text{ kPa}}$$

$$= 1.326\text{ m}^3$$

$$V = V_1 + V_2$$

$$V = 1\text{m}^3 + 1,326\text{m}^3$$

$$V = 2,326\text{m}^3$$

$$m = m_1 + m_2$$

$$m = 4,309\text{kg} + 3\text{kg}$$

$$m = 7,309\text{kg}$$

9/10

$$P = \frac{mRT}{V}$$

$$= \frac{(7,309\text{kg})(0,287\text{kJ/kg}\cdot\text{K})(273+20\text{K})}{2,326\text{m}^3}$$

$$= 269\text{KPa}$$

3,84

known

Superheated water vapor - 15 MPa
350°C

Find!

Q: ideal gas equation 10/10

- b) the generalized compressibility chart
- c) the steam tables

determine the error involved in the first two cases.

equation,

$$a', V = \frac{RT}{P}$$

$$= \frac{0.4615 \times (350 + 273)}{(15000)}$$

$$= 0.01917 \text{ m}^3/\text{kg}$$

$$b_i \quad pr = \frac{P}{P_{CR}}$$

$$TR = \frac{I}{T}$$

$P_{cr} = 22,06 \text{ MPa}$
 $T_{CR} = 697,1 \text{ k}$

$$Pr = \frac{15}{22.06} = 0.68$$

$$TR = \frac{350 + 273}{647,1} = 0,963$$

$$Z = 0.65$$

$$V_1 = Z \times V_{\text{ideal}}$$

$$V_1 = 0.65 \times 0.01917$$

$$V_1 = 0.01246 \text{ m}^3/\text{kg}$$

$$C_1 \quad P = 15 \text{ MPa} \quad T = 350^\circ\text{C} \quad - \text{ from the table}$$

$$V = 0.011481 \text{ m}^3/\text{kg}$$

$$\text{Error percentage} = \frac{V_1 - V}{V}$$

Ideal gas

$$= \frac{0.01246 - 0.011481}{0.011481}$$

$$= 8.52\%$$

$$\text{Percentage error} = \frac{V_1 - V}{V}$$

Super heated

$$= \frac{0.01246 - 0.011481}{0.011481}$$

$$= 8.52\%$$

B-100

KNOWN: V_m^3 TANK CONTAINS 2.841 kg
OF STEAM AT 0.6 MPa

FIND: T_{STEAM} , USING IDEAL GAS LAW
EQUATION

VAN DER WAALS EQUATION, + STEAM TABLES

SCHEMATIC:



ANALYSIS: a.) $\frac{P}{T} = \frac{P_c}{R T_c}$ * given on steam tables 10/10
 $R = 0.4615 \text{ kPa} \cdot \text{m}^3 / \text{kg} \cdot \text{K}$

$$V = \frac{V}{m} = \frac{V}{2.841 \text{ kg}} = 0.3520 \text{ m}^3 / \text{kg}$$

b.) $\frac{P}{T} = \frac{P_c}{R T_c} \Rightarrow T = \frac{P_c}{R} = \frac{(600 \text{ kPa})}{0.4615 \text{ kPa} \cdot \text{m}^3 / \text{kg} \cdot \text{K}} = 457.6 \text{ K}$

$$T = \frac{1}{R} \left(P + \frac{a}{V^2} \right) (V - b) \Rightarrow a = \frac{27 R^2 T_c^2}{64 P_c}$$

$$T_a = 647.1, P_a = 22.06 \text{ MPa} = \frac{27 (0.4615 \text{ kPa} \cdot \text{m}^3 / \text{kg} \cdot \text{K})^2 (647.1 \text{ K})^2}{64 (22.06 \text{ MPa})}$$

$$= 0.00169 \text{ m}^3 / \text{kg}$$

$$T = 0.3520 \text{ m}^3 / \text{kg} - 0.00169 \text{ m}^3 / \text{kg}$$

$$= 465.9 \text{ K}$$

c.) $T = 200^\circ \text{C} \Rightarrow 273 + 200 \text{ K} = 473 \text{ K}$

3-121

KNOWN: A 10-kg MASS OF

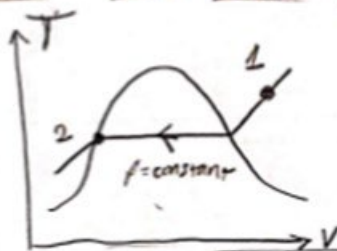
SUPERHEATED REFRIGERANT-134A AT 1.2 MPa AND

70°C IS COOLED AT CONSTANT PRESSURE UNTIL
IT EXITS AT A COMPRESSED HEAT OF 20°C

FIND: PROCESS SHOWN ON T-v CHART,

 ΔV VOLUME, AND ΔU TOTAL ENERGY (INTERNAL)

SCHEMATIC: a.



10/10

ANALYSIS: b. $\Delta V = m(v_2 - v_1)$

$$\Delta V = 10 \text{ kg} (0.000816 \text{ m}^3/\text{kg} - 0.019302 \text{ m}^3/\text{kg})$$

$$= -0.18486 \text{ m}^3$$

c. $\Delta U = m(u_2 - u_1)$

$$= 10 \text{ kg} (78.85 \text{ kJ/kg} - 277.23 \text{ kJ/kg})$$

$$= -1983.8 \text{ kJ}$$

Given Data:

Temperature of steam

$T = 400^\circ\text{C}$

$= 400 + 273$

$= 673\text{ K}$

Specific volume of steam

$v = 0.02\text{ m}^3/\text{kg}$

Property tables, properties of water:Gas constant: $R = 0.4615\text{ kJ/kg}\cdot\text{K}$ critical temperature, $T_{cr} = 647.1\text{ K}$ Critical pressure, $P_{cr} = 22.06\text{ MPa} = 22060\text{ kPa}$ (a) Ideal gas equation

$$P = \frac{RT}{v} = \frac{0.4615 \times 673.1}{0.02} = 15631.78\text{ kPa}$$

Pressure of steam

(b) Reduced temperature

$$T_r = \frac{T}{T_{cr}} = \frac{673.1}{647.1} = 1.0401$$

Pseudo reduced volume,

$$V_r = \frac{V_{actual}}{RT_{cr}/P_{cr}}$$

$$= 1.477$$

9/10

off

Formula pressure of steam: $P = P_r P_{cr}$

$$= 0.57 \times 22060$$

$$= 12574.2\text{ kPa}$$

$$P = 12574.2\text{ kPa}$$

Using interpolation at temp. 400°C and volume $0.02\text{ m}^3/\text{kg}$, P is calculated by:

$$\frac{0.02 - 0.020030}{0.015071 - 0.020030} = \frac{P - 12.5}{16.0 - 12.5}$$

$$6.182 \times 10^{-5} = \frac{P - 12.5}{2.5}$$

$$0.017206 = P = 12.5$$

$$P = 0.017206 \times 12.5 = 12.517\text{ MPa}$$

AVERAGE

L5

Remmygo D30

Christopher Seates

L.C. Huilnes
Kurtin Henning
Clayton Strickling

Problem Statement: Complete this table for

known:

$$T, ^\circ\text{C} = 140, 80 \quad 84/90 = 93\%$$

$$P, \text{kPa} = 200, 950, 500, 800$$

$$h, \text{kJ/kg} = 1800, 3162.2$$

$$x = 0.7, 0.0$$

Find:

Complete the table

Schematic:

$T, ^\circ\text{C}$	P, kPa	$h, \text{kJ/kg}$	x	Phase description
140	200	1800	0.7	
80	950		0.0	
	500			
	800	3162.2		

Assumptions:

no assumptions

Properties:

All needed properties are known

Analysis:

9/10 fill the table

$$h_1 = h_f + x, h_{fg}$$

read the table

Solution plan -

$$① h_f = 504.71 \quad h = 504.71 + 0.7(2201.6)$$

$$h_{fg} = 2201.6 \quad h_1 = 1645.83$$

Phase: Sat. liquid vapour mixture

$$② h_2 = 589.16 + x_2(2144.3) = 1800$$

$$x_2 = 0.56468 \quad P_2 = 361.53 \text{ kPa}$$

Phase: Sat. liquid - vapour mixture

$$③ h_f = h_3 = 752.74 \text{ kJ/kg}$$

$$T_3 = T_{\text{sat}} = 177.66^\circ\text{C}$$

Phase: saturated liq.

$$④ h_4 = 335.24 \text{ kJ/kg} \quad \text{cannot define } x_4$$

Phase: compressed liquid

$$⑤ T_5 = 350^\circ\text{C} \quad \text{cannot define } x_5$$

Phase: Superheated steam

Comments: Most of the information is in the table.

Ternitago D30
Chiller Scales

L.C. Hovers
Refrigerant
Chiller Scales

Problem Statement: Complete this table for refrigerant-134a.

Known:

$T_1, ^\circ\text{F} = 15, 10, 110$
 $P_1, \text{psia} = 80, 70, 180$
 $h_1, \text{Btu/lbm} = 78, 129.46$
 $x = 0.6, 1.0$

Find: complete the table

Schematic:

$T_1, ^\circ\text{F}$	P_1, psia	$h_1, \text{Btu/lbm}$	x	Phase description
15	80	78		
10	70			
110	180	129.46	1.0	

9/10 fill the table

Assumptions: no assumptions.

Properties: All needed properties are known

Analysis:

Solution plan -

$$h_1 = 53.394 + x_1(78.304) = 78$$

$$x_1 = 0.5660$$

$$T_1 = 65.84^\circ\text{F}$$

Phase: Liquid-Vapour mixture

$$h_2 = 16.889 + 0.6(53.394) = 69.152 \text{ Btu/lbm}$$

$$h_2 = 69.152 \text{ Btu/lbm}$$

$$P_2 = 29.759 \text{ psia}$$

Sat. liquid-vapour mixture

$$h_f = h_g = 15.318 \text{ Btu/lbm}$$

Phase: Compressed liquid

Cannot define quality for compressed liquid

$$T_4 = 160^\circ\text{F}$$

Phase: Superheated

Quality cannot be defined for superheated vapor

$$P_5 = 161.16 \text{ psia}$$

$$h_5 = 117.23 \text{ Btu/lbm}$$

Phase: Saturated Vapor

Comment:

use the appropriate equation to find the info you need and look in the table to find the rest of the missing info.

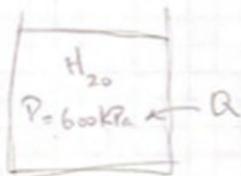
9/10 fill the table

Problem Statement :- A Piston-cylinder Contains 0.005 m^3 of liquid water and 0.9 m^3 of water vapor in equilibrium at 600 kPa . Heat is transferred at constant pressure until the temperature reaches 200°C .

Known :

- Find :
- What is the initial temperature of the water
 - Determine the total mass of the water
 - Calculate the final volume
 - Show the process on a $P-v$ diagram with respect to saturation lines.

Schematic :



Assumption : No Assumptions

Properties : All needed Properties are known

Analysis :

$$V = 0.005 \text{ m}^3 \quad \text{Water Vapor} = 0.9 \text{ m}^3$$

$$x = 0.9$$

$$P = 600 \text{ kPa}$$

$$T_2 = 200^\circ\text{C}$$

8/10 hard to read numbers

a) $T_1 = ? \quad 158.85^\circ\text{C}$

b) $m = ? \quad 7.37 \text{ kg}$

c) $V_2 = ? \quad 2.605 \text{ m}^3$

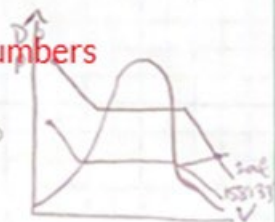
$$v_f = 0.0011 \quad v_g = 0.3560$$

$$m = \frac{0.005}{0.0011} + \frac{0.9}{0.3560} = 7.593 \text{ kg}$$

$$V_2 = (m)(v_g)$$

$$7.593 (0.35212)$$

$$V_2 = 2.603 \text{ m}^3$$



comment :

Use the right formula.

Problem statement A piston-cylinder device initially contains steam at 3.5 MPa, superheated by 5°C. Now, steam loses heat to the surroundings and the piston moves down, hitting a set of stops, at which point the cylinder contains saturated liquid water. The cooling continues until the cylinder contains water at 200°C.

Known

$$P = 3.5 \text{ MPa}$$

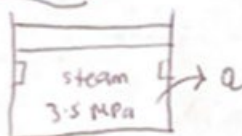
$$\text{superheated} = 5^\circ\text{C}$$

$$T = 200^\circ\text{C}$$

Find

Determine (a) the initial temperature, (b) the enthalpy change per unit mass of the steam by the time the piston first hits the stops, and (c) the final pressure and the quality (if mixture)

Schematic



Assumptions

no assumptions

Properties

All needed properties are known

Analysis

$$P_1 = 3.5 \text{ MPa}$$

$$T_1 = T @ 3.5 \text{ MPa} + 5^\circ\text{C}$$

$$T_2 = 200^\circ\text{C}$$

$$(a) T_1 = 247.56^\circ\text{C}$$

$$(b) \Delta H = -1771.4 \text{ kJ/kg}$$

$$(c) P_2 = 1.555 \text{ MPa} @ 200^\circ\text{C}$$

$$X = 0.0006$$

10/10

$$\Delta H = 1019.7 - 2821.1 = -1771.4$$

$$X = \frac{v_{\text{av}} - v_f}{v_g - v_f} = 0.0006$$

Comments

Use the right formula.

Problem Statement: A 1-m³ tank containing air at 10°C and 350 kPa is connected through a valve to another tank containing 3 kg of air at 35°C and 150 kPa. Now the valve is opened, and the entire system is allowed to reach thermal equilibrium with the surroundings, which are at 20°C. Determine the volume of the second tank and the final equilibrium pressure of air.

Known:

$$V_A = 1 \text{ m}^3$$

$$T_A = 10^\circ\text{C} = 283 \text{ K}$$

$$P_A = 350 \text{ kPa}$$

$$m_B = 3 \text{ kg}$$

$$T_B = 35^\circ\text{C} = 308 \text{ K}$$

$$P_B = 150 \text{ kPa}$$

$$T = 20^\circ\text{C} = 293 \text{ K}$$

Find: Determine the volume of the second tank and the final equilibrium pressure of air.

Schematic:

no sketch

Assumptions: no assumptions.

Properties:

all needed properties are known

Analysis:

Physical law Equation-

$$P_A V_A = m_A R T_A$$

$$V_A = \frac{m_A R T_A}{P_A}$$

$$V_B = \frac{m_B R T_B}{P_B}$$

$$\text{Total mass, } m_T = m_A + m_B$$

$$\text{Total volume, } V_T = V_A + V_B$$

Solution plan-

$$m_A = \frac{P_A V_A}{R T_A} = \frac{350 \times 1}{0.287 \times 283} = 4.309 \text{ kg}$$

$$V_B = \frac{3 \times 0.287 \times 308}{150} = 1.33 \text{ m}^3$$

$$\text{Total mass} = m_T = 4.309 + 3 = 7.309 \text{ kg}$$

$$\text{Total volume} = V_T = 1 + 1.33 = 2.33 \text{ m}^3$$

$$\frac{m_T R T}{V_T} = \frac{7.309 \times 0.287 \times 293}{2.33} = 263.79 \text{ kPa}$$

off

Comments:

change the °C to K

Problem Statement: Determine the specific volume of superheated water vapor at 15 MPa and 350°C. A) Ideal Gas law B) the generalized compressibility chart C) steam tables

Known:

$$P = 15 \text{ MPa}$$

$$T = 350^\circ\text{C}$$

Find: Determine the specific volume of superheated water vapor at 15 MPa and 350°C

Schematic:

no sketch

Assumptions: No assumption

Properties: All needed properties are known

Analysis:

$$V = \frac{RT}{P}$$

$$\frac{255\%}{10/10} \frac{0.01917 - 0.01198}{0.01198} \times 100 = 67\%$$
$$b) \frac{0.0146 - 0.01198}{0.01198} \times 100 = 25\%$$

Solution Plan

A) $V = \frac{RT}{P} \rightarrow R \frac{(350^\circ\text{C} + 273\text{K})}{15 \text{ MPa}} = 0.01917 \text{ m}^3/\text{kg}$ $R = 0.4615$

B) $k = 0.68$
 $T_r = 0.96$
 $Z = 0.65$
 $V = Z \cdot v_{\text{ideal}} \rightarrow 0.65 \cdot 0.01917 = 0.01246 \text{ m}^3/\text{kg}$

C) $V = 0.01198 \text{ m}^3/\text{kg}$

from chart

Comment 58

All is given

Problem Statement: A 1-m³ tank contains 2.841 kg of steam at 0.6 MPa. Determine the temperature of the steam, using
 (a) the ideal-gas equation, (b) the van der Waals equation, and (c) the steam tables.

Known:

$$V = 1 \text{ m}^3$$

$$\text{mass} = 2.841 \text{ kg}$$

$$\text{pressure} = 0.6 \text{ MPa}$$

Find:

Determine the temperature of the steam, using (a) the ideal-gas equation, (b) the van der Waals equation, and (c) the steam tables.

Schematic:

no sketch

Assumptions: no assumptions

Properties:

all needed properties are known

Analysis:

Solution plan -

$$\textcircled{a} \quad PV = RT \quad T_i = \frac{PV}{R} \quad T_i = \frac{600(0.35198)}{0.4615} = 457.61 \text{ K} \quad 10/10$$

$$\textcircled{b} \quad a = \frac{27R^2T^2}{64P} = a = \frac{27(0.4615^2)(2647.3^2)}{64(22090)} = 1.70 \text{ m}^3 \cdot \text{K}^2$$

$$b = \frac{RT_{cr}}{8P_{cr}} = \frac{0.4615(647.1)}{8(22090)} = 0.00167 \text{ m}^3/\text{kg}$$

$$T = \frac{1}{R} \left(P + \frac{a}{V^2} \right) (V - b)$$

$$T = \frac{1}{0.4615} \left(600 + \frac{1.70}{0.35198^2} \right) (0.35198 - 0.00167)$$

$$T = 465.9 \text{ K}$$

$$\textcircled{c} \quad T_c = 200^\circ\text{C}$$

$$= 473 \text{ K}$$

Comments: Use the formula to solve.

21

Christopher Scales

Kerigan Williams
Clayton Strubling

Problem Statement: A 10-kg mass of superheated refrigerant-134a at 12 MPa and 70°C is cooled at constant pressure until it exists as a compressed liquid at 20°C.

- (a) Show the process on a T-v diagram with respect to saturation lines.
 (b) Determine the change in volume.
 (c) Find the change in total internal energy.

Known:

mass = 10-kg
 Pressure = 1.2 MPa
 compressed liquid @ 20°C

Find:

- Show the process on a T-v diagram with respect to saturation lines.
 - Determine the change in volume.
 - Find the change in total internal energy.

Schematic:

NO sketch

Assumptions: no assumptions

Properties:

all needed properties are known

Analysis:

physical law/equation-

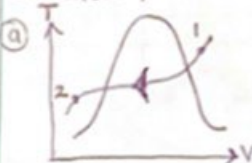
$$\Delta V = m(u_2 - u_1)$$

$$\Delta U = m(V_2 - V_1)$$

$$V_1 = 0.019502 \text{ m}^3/\text{kg}$$

$$V_2 = 0.00816 \text{ m}^3/\text{kg}$$

Solution plan:



(b) $\Delta V = (10\text{-kg})(0.00816 \text{ m}^3/\text{kg} - 0.019502 \text{ m}^3/\text{kg})$
 $= -0.1187 \text{ m}^3$

10/10

(c) $u_1 = 277.23 \text{ kJ/kg}$ $u_2 = 78.85 \text{ kJ/kg}$
 $\Delta u = (10\text{kg})(78.85 \text{ kJ/kg} - 277.23 \text{ kJ/kg})$
 $= -1983.8 \text{ kJ}$

comment: b

All the information for U and V is in the table.

Problem Statement: Steam at 400°C has a specific volume of $0.02 \text{ m}^3/\text{kg}$. Determine the pressure of the steam based on a) the ideal-gas equation, b) the generalized compressibility chart, and c) the steam tables.

Known:

$$T = 400^\circ\text{C}$$

$$v = 0.02 \text{ m}^3/\text{kg}$$

Find: Determine the pressure of the steam based on a) the ideal-gas equation b) the generalized compressibility chart, and c) the steam tables.

Schematic: No sketch

Assumptions: No Assumptions

Properties: All needed Properties are known

Analysis:

Physical law / Equation -

$$\frac{P_0 RT}{v}$$

9/10 hard to read numbers

Solution Plan - ~~1) $\frac{P_0 RT}{v} \rightarrow P = \frac{R(400 + 273.15)}{0.02} = 15.927 \text{ kPa}$~~

2) $T, R = 647.1 \text{ K}$ } from charts
 $R = 0.4615 \text{ kJ/kg}\cdot\text{K}$

$$T_2 = \frac{T}{T_c} \Rightarrow \frac{673}{647.1} = 1.041$$

$$v_R = \frac{v_{\text{actual}}}{R T_c / P_c} \Rightarrow \frac{0.02}{(0.4615 \times 647.1) / 22.06 \text{ MPa}}$$

$$v_R = 1.472$$

c) $P = P_c P_r \Rightarrow 0.57 \times 22.06 = 12574.2 \text{ kPa}$

$$P_r = 0.57$$

Comment: Solve using the right equation.

BELOW AVERAGE

Q. 2. Find Problem # 5.51

$$P = 600 \text{ kPa}$$

$$V = 0.005 \text{ m}^3$$

$$V_g = 0.3 \text{ m}^3$$

$$T = 200^\circ\text{C}$$

as since the liquid water and vapor are in equilibrium at 600 kPa, find the saturation temperature of water corresponding to 600 kPa is 158.8°C

$$\text{So } T = 158.8^\circ\text{C}$$

$$\text{a) at } 600 \text{ kPa}$$

$$\rho_f = 884.1 \text{ kg/m}^3$$

$$\rho_g = 2.36 \text{ kg/m}^3$$

$$\text{mass of liquid water for } V_g = 0.005 \text{ m}^3$$

$$m_f = \frac{V_f}{\rho_f} = \frac{0.005}{884.1} = 5.65 \times 10^{-6} \text{ kg}$$

$$\boxed{m_f = 5.65 \times 10^{-6} \text{ kg}}$$

$$\text{mass of liquid water for } V_g = 0.3 \text{ m}^3$$

$$V_1 = 0.3 \text{ m}^3$$

$$p_1 = 0.1013 \text{ MPa}$$

$$m = \frac{p_1 V_1}{R T_1} = \frac{0.1013 \times 0.3}{0.287 \times 298} = 0.0035 \text{ kg}$$

$$m = 0.0035 \text{ kg}$$

Total mass

$$m = m_1 + m_2$$

$$= 0.0035 + 0.0035$$

$$m = 0.007 \text{ kg}$$

or Volume final

Since, the heat is added at constant pressure, so at 200°C , state will be superheated at 200°C so $p = 0.1013 \text{ MPa}$

$$V_2 = m R T_2 = 0.007 \times 0.287 \times 473$$

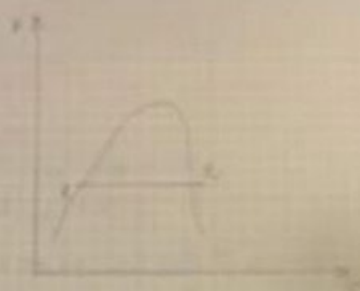
$$= 0.951 \text{ m}^3$$

$$V_2 = 0.951 \text{ m}^3$$

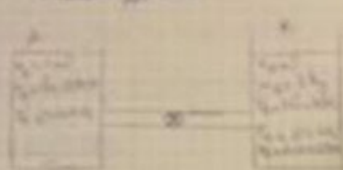
Unreadable

0/10

4)



Problem # 2.10



Determine the volume of the second tank
ideal gas equation

$$P_A V_A = n_A R T_A \quad \text{or } P_A = n_A R T_A / V_A$$

$$\Rightarrow V_A = \frac{n_A R T_A}{P_A}$$

$$= \frac{2.00 \text{ m}^3 \cdot 1.00 \text{ atm}}{1.00 \text{ atm}} = 2.00 \text{ m}^3$$

$V_A = 2.00 \text{ m}^3$

The final pressure of air

Total pressure $P_T = P_A + P_B$

$$P_T = \frac{P_A V_A}{V_T} = \frac{1.00 \text{ atm} \cdot 2.00 \text{ m}^3}{5.00 \text{ m}^3} = 0.40 \text{ atm}$$

Problem # 2.10



Determine the volume of the second tank
ideal gas equation

$$P_A V_A = n_A R T_A \quad \text{or } P_A = n_A R T_A / V_A$$

$$\Rightarrow V_A = \frac{n_A R T_A}{P_A}$$

$$= \frac{2.00 \text{ m}^3 \cdot 1.00 \text{ atm}}{1.00 \text{ atm}} = 2.00 \text{ m}^3$$

$V_A = 2.00 \text{ m}^3$

The final pressure of air

Total pressure $P_T = P_A + P_B$

$$P_T = \frac{P_A V_A}{V_T} = \frac{1.00 \text{ atm} \cdot 2.00 \text{ m}^3}{5.00 \text{ m}^3} = 0.40 \text{ atm}$$

$$m = 2.568 \times 10^{-3} \text{ kg}$$

$$\text{Shell volume, } V = \pi r^2 h = 1.43 \times 10^{-3} \text{ m}^3$$

$$P = \frac{mg + \rho g V}{A} = \frac{2.568 \times 10^{-3} \times 9.8 + 1.0 \times 10^3 \times 9.8 \times 1.43 \times 10^{-3}}{1.0}$$

$$= 265.78 \text{ N/m}^2$$

$$\text{So } P_f = 265.78 \text{ N/m}^2$$

Problem 3-100

Problem: A 1-m³ tank contains 2.841 kg of steam at 0.6 MPa. Determine the temp. of the steam, using (a) the ideal-gas equation, (b) the van-der Waals equation, and (c) the steam tables.

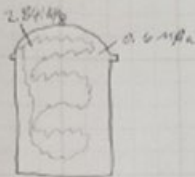
Known:

Mass, 2.841; Pressure, 0.6 MPa

Find:

Temperature.

Schematic:



Assumption: need to find specific volume.

Properties:

$$R = 0.4615 \text{ kPa}$$

$$T_{cr} = 647.3 \text{ K}$$

$$P_{cr} = 22.09 \text{ MPa}$$

Analysis:

$$v = \frac{V}{m} \quad P v = R T \quad a = \frac{27 R^2 T_{cr}^2}{64 P_{cr}} \quad b = \frac{R T_{cr}}{8 P_{cr}}$$

$$T = \frac{1}{R} \left(P + \frac{a}{v^2} \right) (v - b)$$

$$(a) \quad v = \frac{1}{2.841} = 0.35198 \text{ m}^3/\text{kg}$$

$$T_i = \frac{P v}{R} = \frac{600(0.35198)}{0.4615} = 451.61 \text{ K}$$

10/10

$$(b) \quad a = \frac{27(0.4615^2)(647.3^2)}{64(22.09)} = 1.700$$

$$b = \frac{0.4615(647.3)}{8(22.09)} = 0.00169$$

$$T = \frac{1}{0.4615} \left(600 + \frac{1.700}{0.35198^2} \right) (0.35198 - 0.0009)$$

$$T = 465.9 \text{ K}$$

$$(c) \quad T_c = 200^\circ\text{C}$$

$$T = 473 \text{ K}$$

Problem 3-84

Problem: Determine the specific volume of super heated water vapor at 15 MPa and 350°C using (A) The ideal gas equation, (B) The generalized compressibility chart, and (C) The steam tables. Also determine the error involved in the first two cases.

Known: pressure, 15 MPa; Temp., 350°C

Find: specific volume; error %.

Schematic: None

Arrange work in the proper order

Assumption: have to find gas constant, P_R , and T_R

Properties: $R = 0.4615 \text{ kJ/kg} \cdot \text{K}$
 $P_R = 22.06 \text{ MPa}$
 $T_R = 647.1 \text{ K}$

Analysis: $P_R = \frac{P}{P_R}$ $T_R = \frac{T}{T_R}$ $V = \frac{RT}{P}$ $V_1 = Z \cdot V_{ideal}$

$$(a) \quad V = \frac{(0.4615) \cdot (350 + 273)}{(15,000 \text{ kPa})} = 0.01917 \text{ m}^3/\text{kg}$$

$$Z = \frac{0.01917 - 0.011481}{0.011481}$$

$$\% = 46.97\%$$

$$(b) \quad P_R = \frac{15}{22.06} = 0.68$$

10/10

$$T_R = \frac{350 + 273}{647.1} = 0.963$$

$$V_1 = 0.68 \cdot 0.01917$$

$$V_1 = 0.01244 \text{ m}^3/\text{kg}$$

$$Z = \frac{0.01244 - 0.011481}{0.011481}$$

$$\% = 8.52\%$$

$$Z = 0.65$$

(C)

$$V = 0.011481 \text{ m}^3/\text{kg}$$

3-121 You worked 3-131 here not 3.121

Known: $T = 400^\circ\text{C}$ $\times$ 673 K , $P_0 = 0.5\text{ MPa}$
 $v = 0.02\text{ m}^3/\text{kg}$

Find: a) Ideal gas pressure based on:
 1) Ideal gas equation
 2) generalized compressibility chart
 3) steam tables

Assumption: Assume this is a superheated vapor. At 400°C , $P = 12.5\text{ MPa}$
 At 400°C , 450 kPa , $P = 15\text{ MPa}$

Analysis a) $Pv = RT \rightarrow P = \frac{RT}{v} \rightarrow P = \frac{0.4615 \cdot 673.1}{0.02}$

$P = 15,531.782\text{ kPa}$

b) $v_u = \frac{v}{R_{T_{cr}}/P_{cr}} \rightarrow \frac{0.02}{(0.4615 \cdot 673.1)/22060} = 1.477$

$T_u = \frac{T}{T_{cr}} = \frac{673.1}{647} = 1.0401$

9/10

$P = P_u \cdot P_{cr} \rightarrow P = 0.57 \cdot 22060 = 12,574.2\text{ kPa}$

c) $\frac{0.02 - 0.020030}{0.015671 - 0.020030} = \frac{P - 12.5}{15 - 12.5}$

$6.882^\circ\text{C} - 3 = \frac{P - 12.5}{2.5}$

$0.017205 = \frac{P - 12.5}{2.5}$
 $P = 12.517205\text{ MPa}$

3-131

Knowns

$v = 0.02 \text{ m}^3/\text{kg}$ Data from table - $T_{\text{sat}} = 647.1 \text{ K}$
 $T = 400^\circ\text{C} = 673 \text{ K}$ $R = 0.4615 \text{ kJ/kg}$ $P_{\text{sat}} = 22060 \text{ kPa}$

Find

pressure of the steam

assumptions

assume the pressure of the steam based off the steam table

Graded already

analysis

A) $P = \frac{RT}{v} = \frac{(0.4615)(673.1)}{0.02} = 15531.782 \text{ kPa}$

B) $T_r = \frac{T}{T_{\text{sat}}} = \frac{673.1}{647.1} = 1.0401$

$v_r = \frac{v}{v_{\text{sat}}} = \frac{0.02}{(0.4615 \cdot 647.1)/22060} = 1.477$

$P = P_r P_{\text{sat}} = (0.57)(22060) = 12574.2 \text{ kPa}$

C) $v_1 = 0.020030 \text{ m}^3/\text{kg}$

$v_2 = 0.015671 \text{ m}^3/\text{kg}$

$\frac{0.02 - 0.020030}{0.015671 - 0.020030} = \frac{P - 12.5}{15 - 12.5}$

$6.882 \cdot 10^{-3} = \frac{P - 12.5}{2.5}$ $0.017205 = P - 12.5$

$P = 0.017205 + 12.5$

$P = 0.017205 + 12.5 = 12.517 \text{ MPa}$

**THERMODYNAMICS I
FALL 2021**

HOMEWORK 4

TOPICS COVERED IN HOMEWORK 4

Energy Analysis of Closed Systems

HOMEWORK #4 QUESTIONS

**4.10E, 4.13, 4.15, 4.20,
4.22, 4.29, 4.60E, 4.74, 4.137, 1.141**

ABOVE AVERAGE

Water Evans

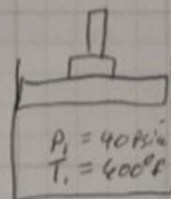
Problem 4-10E

Statement: A frictionless piston-cylinder device contains 16 lbm of superheated water vapor at 40 psia and 600°F. Steam is now cooled at constant pressure until 70 percent of it, by mass, condenses. Determine the work done during this process.

Known: Specific Volume, 40 psia; Temp., 600°F.

Find: Work done.

Schematic:



10/10

Assumption: Find specific volume of steam. Remaining steam 30%

Properties: $v_1 = 15.686 \text{ ft}^3/\text{lbm}$

$v_f = 0.0175 \text{ ft}^3/\text{lbm}$

$v_g = 10.501 \text{ ft}^3/\text{lbm}$

Analysis: $v_2 = v_f + x(v_g - v_f)$

$W = mP_1(v_2 - v_1)$

$v_2 = 0.0175 + [0.3 \times (10.501 - 0.0175)]$
 $= 3.1625 \text{ ft}^3/\text{lbm}$

$W = 16 \cdot 40 \cdot (3.1625 - 15.686)$
 $= -8015.04 \text{ psia} \cdot \text{ft}^3$

$1 \text{ Btu} = 5.41 \text{ psia} \cdot \text{ft}^3$

$W = -8015.04 \cdot \frac{1}{5.41}$

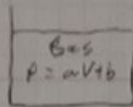
$W = -1482 \text{ Btu}$

Statement: A gas is compressed from an initial volume of 0.42 m^3 to a final volume of 0.12 m^3 . During the quasi-equilibrium process, the pressure changes with volume according to the relation $p = aV + b$, where $a = -1200 \text{ kPa/m}^3$ and $b = 600 \text{ kPa}$. Calculate the work done during this process (a) by plotting the process on a p - V diagram and finding the area under the process curve and (b) by performing the necessary integrations.

Known: initial volume, 0.42 m^3 ; final volume, 0.12 m^3 .

Find: area under process curve and work done

Schematic:



Assumption: None

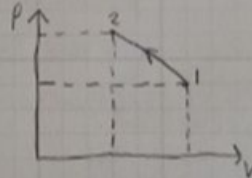
Properties: $a = -1200 \text{ kPa/m}^3$
 $b = 600 \text{ kPa}$

10/10

Analysis: $p = aV + b$

$$P_1 = -1200 \cdot 0.42 + 600 = 96 \text{ kPa}$$

$$P_2 = -1200 \cdot 0.12 + 600 = 456 \text{ kPa}$$



$$\begin{aligned} \text{(a)} \quad W &= \frac{1}{2} (V_2 - V_1) (P_2 - P_1) + (V_2 - V_1) P_1 \\ &= \frac{1}{2} (0.12 - 0.42) (456 - 96) + (0.12 - 0.42) 96 \\ &= \boxed{-82.8} \end{aligned}$$

$$\begin{aligned} \text{(b)} \quad W &= \int_{V_1}^{V_2} p \, dV \\ &= \int_{0.42}^{0.12} (-1200V + 600) \, dV \\ &= \boxed{-82.8 \text{ kJ}} \end{aligned}$$

Homework #4 | Ch. 4 4-15

- ① Expansion and compression processes in a piston-cylinder device is polytropic ($PV^n = C$). Calculate the work done when gas expands from 350 kPa and 0.03 m³ to a final volume of 0.2 m³ for case of $n=1.5$.

②  350 kPa $n=1.5$
 $V_1 = 0.03 \text{ m}^3$ $V_2 = 0.2 \text{ m}^3$ 10/10

③ $PV^n = C$ $C = P_1 V_1^n = 350 \times (0.03)^{1.5} = 1.81$
 $W = 2 \text{ kJ}$ $P_2 V_2^n = C$ $P_2 = \frac{C}{V_2^n}$

④ $PV^n = C$ $W = \frac{P_1 V_1 - P_2 V_2}{n-1}$ $P_2 = \frac{C}{V_2^n}$

- ⑤ Need to know P_2 to complete problem

⑥ $P_2 = \frac{1.81}{(0.2)^{1.5}} = 20.23 \text{ kPa}$

$W = \frac{(350 \times 0.03) - (20.23 \times 0.2)}{1.5 - 1} = 12.908 \text{ kJ}$

- ⑦ As the gas expands in the piston-cylinder the work done is 12.908 kJ.

- ① Piston Cylinder device contains 0.15 kg of air initially at 2 MPa and 350°C. The air is first expanded isothermally to 500 kPa, then compressed polytropically with exponent of 1.2 to the initial pressure, and finally compressed at constant pressure. Find the boundary work for each process and net work for the cycle.

$$V_1 = \frac{mRT_1}{P_1} = \frac{0.15 \times 286.9 \times 623}{2 \times 10^6} = 0.0134 \text{ m}^3$$

② $\boxed{0.15 \text{ kg}}$

$P_1 = 2 \text{ MPa}$ $T_1 = 350^\circ\text{C}$ - isothermal
 $\approx 623 \text{ K}$ - polytropic, $n = 1.2$

$$V_1 - V_4$$

10/10

- ③ - Temperature is constant
 - $PV = C$ constant pressure

- ④ For isothermal, $W_{12} = mRT \ln \frac{P_1}{P_2}$ For isobaric, $W_{34} = P \Delta V$
 For polytropic, $W_{23} = \frac{P_2 V_2 - P_3 V_3}{1 - n}$ $P_3 (V_4 - V_3)$

- ⑤ Need work done for all 3 processes to calculate net work

⑥ $W_{12} = (0.15)(286.9) \ln \left(\frac{2}{0.5} \right) = 37.168 \text{ kJ}$ $V_2 = \left(\frac{2}{0.5} \right)^{\frac{1}{1.2}} \times 0.0134 \text{ m}^3$
 $W_{23} = \frac{(2 \times 10^6 \times 0.0169) - (500 \times 10^3 \times 0.0536)}{1 - 1.2} = -35000 \text{ J} = -35 \text{ kJ}$ $V_3 = \left(\frac{2}{0.5} \right)^{\frac{1}{1.2}} \times 0.0536$
 $W_{34} = 2 \times 10^6 (0.0134 - 0.0169) = -7000 \text{ J} = -7 \text{ kJ}$
 Net work = $37.168 - 35 - 7 = -4.832 \text{ kJ}$

Problem # 4.22

$$m = 1 \text{ kg}$$

$$T_1 = 90^\circ\text{C}$$

$$x = 10\% = 0.1$$

$$P_2 = 800 \text{ kPa}$$

$$T_2 = 250^\circ\text{C}$$

Determine the total work

at $T_1 = 90^\circ\text{C}$ we have $P_1 = 70.183 \text{ kPa}$

$$v_f = 0.001036 \text{ m}^3/\text{kg}$$

$$v_g = 2.3593 \text{ m}^3/\text{kg}$$

$$v_1 = v_f + x v_g$$

$$v_1 = 0.001036 + 0.1(2.3593 - 0.001036)$$

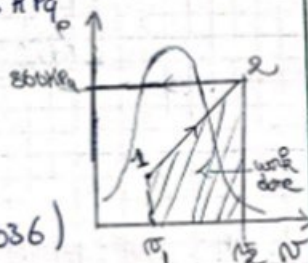
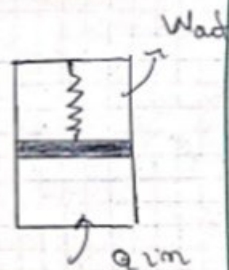
$$v_1 = 0.23686 \text{ m}^3/\text{kg}$$

$$\text{At } T_2 = 250^\circ\text{C } v_2 = 0.29321 \text{ m}^3/\text{kg}$$

$$W_{12} = \left(\frac{P_1 + P_2}{2} \right) (v_2 - v_1) \times m$$

$$= \left(\frac{70.183 + 800}{2} \right) \times 1 (0.293686 - 0.23686)$$

$$W_{12} = 24.52 \text{ kJ}$$



Problem # 4.29

Complete The Table

1) $Q_{in} = 280 \text{ kJ}$, $E_1 = 1020 \text{ kJ}$; $E_2 = 860 \text{ kJ}$, $m = 3 \text{ kg}$
 $E_{in} - E_{out} = E_2 - E_1$

$Q_{in} - W_{out} = E_2 - E_1$
 $\Rightarrow 280 - W_{out} = 860 - 1020$

$\Rightarrow W_{out} = 280 - 860 + 1020 = 440 \text{ kJ}$

$W_{out} = 440 \text{ kJ} \Rightarrow W_{out} = 440 \text{ kJ}$

$E_{in} - E_{out} = m(e_2 - e_1)$

$\Rightarrow e_2 - e_1 = \frac{E_{in} - E_{out}}{m} = \frac{E_2 - E_1}{m}$

$= \frac{860 - 1020}{3} \text{ kJ} = -53.33 \text{ kJ/kg}$

$e_2 - e_1 = -160 \text{ kJ/kg}$

10/10

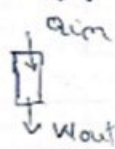
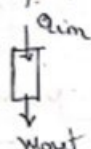
2) $Q_{in} = -350 \text{ kJ}$, $W_{out} = 130 \text{ kJ}$, $E_1 = 550 \text{ kJ}$, $m = 5 \text{ kg}$

$Q_{in} - W_{out} = E_2 - E_1$

$-350 - 130 = E_2 - 550$

$\Rightarrow E_2 = 70 \text{ kJ}$

$E_2 = 70 \text{ kJ}$



$$e_2 - e_1 = \frac{E_2 - E_1}{m}$$

$$= \frac{70 - 550}{5}$$

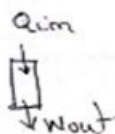
$$e_2 - e_1 = -96 \text{ KJ/Kg}$$

3.) $W_{out} = 260 \text{ KJ}$, $E_1 = 300 \text{ KJ}$, $m = 2 \text{ kg}$, $e_2 - e_1 = -150 \text{ KJ/Kg}$

$$e_2 - e_1 = \frac{E_2 - E_1}{m} \Rightarrow E_2 = m(e_2 - e_1) + E_1$$

$$\Rightarrow E_2 = 2(-150) + 300$$

$$E_2 = 0 \text{ KJ}$$



$$Q_{in} - W_{out} = E_2 - E_1$$

$$Q_{in} - 260 = 0 - 300$$

$$\Rightarrow Q_{in} = -40 \text{ KJ}$$

4.) $Q_{in} = 300 \text{ KJ}$, $E_1 = 750 \text{ KJ}$, $E_2 = 500 \text{ KJ}$, $m = 1 \text{ kg}$

$$Q_{in} - W_{out} = E_2 - E_1$$

$$300 - W_{out} = 500 - 750$$

$$\Rightarrow W_{out} = 500 - 750$$

$$\Rightarrow W_{out} = -250 \text{ KJ}$$



$$e_2 - e_1 = \frac{E_2 - E_1}{m}$$

$$= \frac{500 - 750}{1}$$

$$e_2 - e_1 = -250 \text{ KJ/Kg}$$

5) $Q_{in} = ?$; $W_{out} = -200 \text{ kJ}$; $E_2 = 300 \text{ kJ}$; $m = 2 \text{ kg}$; $e_2 - e_1 = 100 \text{ kJ/kg}$

$$e_2 - e_1 = (E_2 - E_1) / m$$

$$\Rightarrow E_1 = -m(e_2 - e_1) + E_2$$

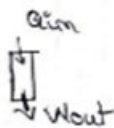
$$= -2 \times (-100) + 300$$

$$\boxed{E_1 = 500 \text{ kJ}}$$

$$Q_{in} - W_{out} = E_2 - E_1$$

$$\Rightarrow 300 - 500 = Q_{in} - (-200)$$

$$\Rightarrow \boxed{Q_{in} = -400 \text{ kJ}}$$



$Q_{in} \text{ (kJ)}$	$W_{out} \text{ (kJ)}$	$E_1 \text{ (kJ)}$	$E_2 \text{ (kJ)}$	$m \text{ (kg)}$	$(e_2 - e_1) \text{ (kJ/kg)}$
280	<u>440</u>	1020	860	3	<u>-53.33</u>
-350	130	55	<u>70</u>	5	<u>-96</u>
-40	260	800	<u>0</u>	2	-150
300	<u>550</u>	750	500	1	<u>-250</u>
<u>-400</u>	-200	<u>500</u>	300	2	-100

Problem # 4.60E

$$P_1 = 15 \text{ Psia}$$

$$T_1 = 80 \text{ F}$$

$$T_2 = 200 \text{ F}$$

$$C_v = 0.158 \text{ Btu/lbm}\cdot\text{R}$$

$$R = 0.04513 \text{ Btu/lbm}\cdot\text{R}$$

The process is Isobaric so $P_1 = P_2 = 15 \text{ Psia}$
 & determine the work done

$$Q_{in} - W_{out} = E_2 - E_1$$

$$Q_{in} - W_{out} = m C_v (T_2 - T_1)$$

$$Q_{in} - W_{out} = C_v (T_2 - T_1)$$

$$W_{out} = P (V_2 - V_1)$$

$$= R (T_2 - T_1)$$

$$= 0.04513 \times (200 - 80)$$

10/10

$$W_{out} = 5.416 \text{ Btu/lbm}$$

determine heat transfer

$$Q_{in} = C_v (T_2 - T_1) + W_{out}$$

$$\Rightarrow Q_{in} = 0.158 \times (200 - 80) + 5.416$$

$$= 24.38 \text{ Btu/lbm}$$

$$\Rightarrow Q_{in} = 24.38 \text{ Btu/lbm}$$

	HW 4	4-74
Statement	A piston-cylinder device contains 2.2 kg of nitrogen initially at 100 kPa and 25°C. The nitrogen is now compressed slowly in a polytropic process during which $Pv^{1.3} = \text{constant}$ until the volume is reduced by one-half. Determine the work done and the heat transfer for this process.	
Known	2.2 kg of N, $P_1 = 100 \text{ kPa}$, $T_1 = 25^\circ\text{C}$, $n = 1.3$	
Find	Work done and heat transfer	
Assumptions	$P_1 v_1^{1.3} = P_2 v_2^{1.3}$ $\frac{P_2 v_2^{1.3}}{P_1 v_1^{1.3}} = 1$	
Properties	$E_{in} - E_{out} = \Delta E$ / $W_b - Q_{out} = \Delta U$	
Analysis	$P_2 = P_1 \left(\frac{v_1}{v_2} \right)^{1.3} \rightarrow 100(2)^{1.3} = 246.2 \text{ kPa}$	
	$T_2 = \frac{246.2(298)}{2^{1.3}} = 366.9 \text{ K}$	
	$W_b = \frac{1}{1-n} m R (T_2 - T_1) = - \frac{(2.2)(0.2968)(366.9 - 298)}{1 - 1.3} = 149.9 \text{ kJ}$	
	$W_b - Q_{out} = m C_v (T_2 - T_1)$	
	$149.9 - Q_{out} = (2.2)(0.749)(366.9 - 298)$	
	$149.9 - Q_{out} = 112.796$	
	$-Q_{out} = -37.124$	
	$Q_{out} = 37.124 \text{ kJ}$	

10/10

Navy

ADVISOR
NAVY
NAVY

4-137

Given

$$V = 2 \text{ m}^3$$

$$P_1 = 1000 \text{ kPa}$$

$$T_1 = 127^\circ \text{C}$$

$$P_1 V_1 = P_2 V_2$$

$$V_2 = 2 + 2 = 4 \text{ m}^3$$

$$P_2 = P_1 \frac{V_1}{V_2}$$

$$P_2 = 1000 \left(\frac{2}{4} \right) = 500 \text{ kPa}$$

$$P_2 = 500 \text{ kPa}$$

Use format given

9/10

$$4-141$$

$$m = 0.35 \text{ kg}$$

$$P_1 = 3.5 \text{ MPa}$$

$$\Delta T = 7.4^\circ\text{C}$$

$$T_3 = 200^\circ\text{C}$$

use given format

$$P_1 = 3.5 \text{ MPa}$$

$$T_{\text{sat}} = 242.56^\circ\text{C}$$

$$T_1 = T + \Delta T_{\text{sat}}$$

$$242.56 + 7.4 = 249.96^\circ\text{C}$$

9/10

$$V_1 = 0.05706 + \frac{(249.96 - 242.56)(0.05876 - 0.05706)}{(250 - 242.56)}$$

$$V_1 = 0.05875 \text{ m}^3/\text{kg}$$

$$u_1 = 2603 + \frac{(249.96 - 242.56)(2624 - 2603)}{(250 - 242.56)}$$

$$u_1 = 2623.9 \text{ kJ/kg}$$

$$P_2 = P_1 = 3.5 \text{ MPa}$$

$$x_2 = 0 \quad V_2 = 0.001235 \text{ m}^3/\text{kg}$$

$$V_3 = V_f + x_3 V_g$$

$$0.001235 = 0.001157 + x_3 (0.12721 - 0.001157)$$

$$x_3 = 0.000618$$

$$850.46 + (0.000618)(1743.1) = 851.537 \text{ kJ/kg}$$

$$P_3 = 155.9 \text{ kPa}$$

$$4-141$$

$$W = m P_1 (V_1 - V_2)$$

$$(0.35)(3500)(0.05875 - 0.001235)$$

$$= 70.45 \text{ J}$$

$$W - Q_{\text{out}} = m(u_2 - u_1)$$

$$= 70.45 - (0.35(1045.4 - 2623.9))$$

$$= 622.925 \text{ kJ/kg}$$

$$= 70.45 - (0.35(151.537 - 2623.9))$$

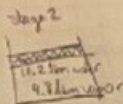
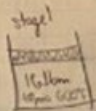
$$= 690.777 \text{ kJ}$$

BELOW AVERAGE

4.10E) A frictionless Piston-Cylinder device contains 16 lbm of superheated water vapor at 40 psia and 600°F. Steam is now cooled at constant pressure until 70% of it, by mass, condenses. Determine work done during this process.

Known: $m = 16 \text{ lbm}$ 70% condenses, so 30% left
 $P = 40 \text{ psia}$ $16 \times 0.3 = 4.8 \text{ lbm}$
 $T = 600^\circ\text{F}$
 $x = 0.3$

Schematic:



Assumptions: 70% condenses, so 30% left
 Constant P , so isobaric

3/10

Properties: All needed properties are known

Analysis: @ 40 psia: $v_g = 0.01715$ (0.3)(16.501)
 $v_g = 3.167$

$$\frac{V_1}{16} = 15.686$$

$$\frac{V_2}{4.8} = 3.167$$

$$V_1 = 250.976$$

$$V_2 = 15.204$$

X? Units?

X Units?

$$W = 40(15.204 - 250.976)$$

$$= -9432.88 \left(\frac{1 \text{ lbf} \cdot \text{ft}}{144 \text{ in}^2 \cdot \text{ft}^2} \right)$$

$$W = -1745.199 \text{ Btu}$$

Comments: The negative sign means work done on the system

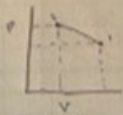
9.15) A gas is compressed from an initial vol. of 0.12 m^3 to a final volume of 0.02 m^3 . During the quasi-equilibrium process, the P changes with volume according to the relation $P = aV + b$ where $a = -1200 \text{ kPa/m}^3$ and $b = 600 \text{ kPa}$. Calculate work done during process (a) by plotting on P-v diagram and finding the area under the curve and (b) by performing the necessary integration.

Known: $V_1 = 0.12 \text{ m}^3$ $a = -1200 \text{ kPa/m}^3$
 $V_2 = 0.02 \text{ m}^3$ $b = 600 \text{ kPa}$
 $P = aV + b$

Find: Work done, W, during the process

10/10

Schematic:



Assumptions: total area under curve on PV diagram is total work

Properties: all properties are known

Analysis: $P = aV + b$
 $P_1 = (-1200)(0.12) + 600 = 96$
 $P_2 = (-1200)(0.02) + 600 = 456$

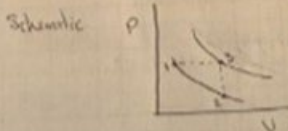
a) $W = \frac{1}{2}(V_1 - V_2)(P_1 + P_2)$
 $= \frac{1}{2}(0.12 - 0.02)(96 + 456)$
 $W = -82.8 \text{ kJ}$

b) $W = \int_{V_1}^{V_2} (1200V + 600) dV = 1200 \frac{V^2}{2} \Big|_{0.12}^{0.02} + 600V \Big|_{0.12}^{0.02}$
 $= \frac{1}{2}(8)(0.02) + (-1200)(0.02) + 152$
 $W = -82.8 \text{ kJ}$

comments: both are ways to find W accurately

4-20) A piston-cylinder device contains 2.15 kg of air initially at 2 MPa and 350°C. The air is first expanded isothermally to 500 kPa, then compressed polytropically with a polytropic exponent of 1.2 to the initial P_1 , and finally compressed at the constant P_1 to the initial state. Determine the boundary work for each process and the net work of the cycle.

Known: Stage 1: $n = 2.15 \text{ kg}$
 $P_1 = 2 \text{ MPa}$
 $T_1 = 350^\circ\text{C}$
 Stage 2: isothermal,
 $T = 350^\circ\text{C}$
 Stage 3: polytropic
 $P = 2 \text{ MPa}$
 $n = 1.2$
 Stage 4: initial state (a)



Assumption: Stage 2 = isothermal, so $T_2 = T_1$
 Stage 3 = polytropic, so $P_3 V_3^n = P_4 V_4^n$
 Stage 4 = initial state, isobaric, so $P_3 = P_4 = P_1$

Properties: All needed properties are known

Analysis: $W_{12} = mRT \ln\left(\frac{P_1}{P_2}\right)$
 $= (2.15)(0.287)(350) \ln\left(\frac{2000}{500}\right)$
 $= 37.18 \text{ kJ}$
 $W_{12} = \frac{mRT_1}{1-n} \left[\left(\frac{P_1}{P_2}\right)^{\frac{n-1}{n}} - 1 \right]$
 $= \frac{(2.15)(0.287)(350)}{1-1.2} \left[\left(\frac{2000}{500}\right)^{\frac{1.2-1}{1.2}} - 1 \right]$
 $= 0.0134 \text{ m}^3$

$W_{34} = P_1(V_4 - V_3) = 2000(0.0134 - 0.017)$
 $= -7.2 \text{ kJ}$

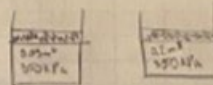
$P_1 V_1^n = P_2 V_2^n$
 $V_2 = \left(\frac{P_1}{P_2}\right)^{\frac{1}{n}} V_1$
 $= \left(\frac{2000}{500}\right)^{\frac{1}{1.2}} (0.0134) = 0.017 \text{ m}^3$
 $W_{23} = \frac{P_2 V_2 - P_3 V_3}{1-n} = \frac{(500)(0.017) - (2000)(0.0134)}{1-1.2}$
 $= \frac{-21.5}{-0.2} = 107.5 \text{ kJ}$
 $W_{34} = \frac{mRT_3}{1-n} \left[\left(\frac{P_3}{P_4}\right)^{\frac{n-1}{n}} - 1 \right]$
 $= \frac{(2.15)(0.287)(350)}{1-1.2} \left[\left(\frac{2000}{2000}\right)^{\frac{1.2-1}{1.2}} - 1 \right]$
 $= 0.0134 \text{ m}^3$

$W_{net} = W_{12} + W_{23} + W_{34}$
 $= 37.18 - 35 - 7$
 $= -5.02 \text{ kJ}$

Comments: negative work indicates work being done on the system

4.15) During some actual expansion and compression processes in piston-cylinder devices, the gases have been observed to satisfy the relationship $PV^n = C$, where n and C are constants. Calculate the work done when a gas expands from 350 kPa and 0.03 m^3 to a final vol. of 0.2 m^3 for the case of $1.5 - n$.

Known: $P_1 = 350 \text{ kPa}$
 $V_1 = 0.03 \text{ m}^3$ $V_2 = 0.2 \text{ m}^3$
 $n = 1.5$

Schematic:  $P_1 V_1^n = P_2 V_2^n$
 $W = \frac{P_1 V_1 - P_2 V_2}{1 - n}$ because polytropic

Assumptions: Piston-cylinder device, so m & P are constant, but V changes

Properties: All needed properties are known

7/10

Analysis:

$$P_1 V_1^n = P_2 V_2^n$$

$$(350)(0.03)^{1.5} = P_2 (0.2)^{1.5}$$

$$20.33 = P_2$$

$$W = \frac{(350)(0.03) - (20.33)(0.2)}{1 - 1.5}$$

$$W = -12.86 \text{ kJ}$$

Comments: negative work means that work was done on the system

Problem 4-22

1 kg of water that is initially at 90°C with a quality of 10 percent occupies a spring-loaded piston-cylinder device, such as that in Fig. P4-22. This device is now heated until the pressure rises to 800 kPa and the temperature is 250°C. Determine the total work produced during this process, in kJ.

Known: $m = 1 \text{ kg}$, $T(i) = 90^\circ\text{C}$, $x = 10\% \Rightarrow .10$, $P(f) = 800 \text{ kPa}$, $T(f) = 250^\circ\text{C}$

Find: The total work

Schematic:



FIGURE P4-21

10/10

Assumptions: Since we are given x , we would need to use it to find the change in specific volume. We would need to also look for the pressure at 90°C to find the change in pressure as well.

Properties: All the properties are given

Analysis: To find total work first we need to find the change in specific volume and the change in pressure as well. To do that we first need to find v_1 and v_2 for specific volume and p_1 for change in pressure.

$$v_1 = v(f) + x v(fg) \quad v_2 = .2932 \text{ m}^3/\text{kg} \quad P_1 = 70.183 \text{ kPa}$$

$$v_1 = 0.001036 \text{ m}^3/\text{kg} + (.10)(2.358264 \text{ m}^3/\text{kg})$$

$$v_1 = .2368 \text{ m}^3/\text{kg}$$

Now use the work formula to find the total work.

$$W(\text{total}) = ((P_1 - P_2)/2)(m)(v_2 - v_1)$$

$$W(\text{total}) = ((70.183 \text{ kPa} - 800 \text{ kPa})/2)(1 \text{ kg})(.2932 \text{ m}^3/\text{kg} - .2368 \text{ m}^3/\text{kg})$$

$$W(\text{total}) = 24.54 \text{ kJ}$$

Problem 4-29:

Complete each line of the following table on the basis of the conservation of energy principle for a closed system.

Known: No properties are given

Find: fill in the blanks on the table

Schematic: The table given

Show details of the analyses.

Assumptions: $e_2 - e_1$ is not the same as $E_2 - E_1$

Properties: No properties are not given

Analysis:

Equation: use the formulas below to fill in the blanks

$$Q(\text{in}) - W(\text{out}) = E_2 - E_1 \text{ \& } e_2 - e_1 = (E_2 - E_1)/m$$

5/10

Q(in) kJ	W(out) kJ	E1 kJ	E2 kJ	m	e2-e1
280	440	1020	860	3	-53.3
-350	130	550	70	5	-96
-40	260	300	0	2	-150
300	550	750	500	1	-250
-400	-200	500	300	2	-100

Problem 4-60E

A piston-cylinder device containing carbon-dioxide gas undergoes an isobaric process from 15 psia and 80°F to 200°F. Determine the work and the heat transfer associated with this process, in Btu/lbm.

Known: $T_1 = 80\text{ F}$, $T_2 = 200\text{ F}$,

Find: Determine the work and heat transfer

Schematic: None

10/10

Assumptions: The temperature is going up so there is heat going in.

Properties: All are known

Analysis:

Equation: use the work formula for temperature to find the work and then use the energy balance formula, for heat and work, to find the heat transfer

$$W(\text{out}) = R(T_2 - T_1)$$

$$W(\text{out}) = (.04513 \text{ Btu/lbm})(200\text{ F} - 80\text{ F})$$

$$W(\text{out}) = 5.4156 \text{ Btu/lbm}$$

$$Q(\text{in}) - W(\text{out}) = C_v(T_2 - T_1)$$

$$Q(\text{in}) = C_v(T_2 - T_1) + W(\text{out})$$

$$Q(\text{in}) = (.158)(120\text{ F}) + 5.4156 \text{ (Btu/lbm)}$$

$$Q(\text{in}) = 24.3576 \text{ (Btu/lbm)}$$

Problem 4-74

A piston-cylinder device contains 2.2 kg of nitrogen initially at 100 kPa and 25°C. The nitrogen is now compressed slowly in a polytropic process during which $PV^{1.3} = \text{constant}$ until the volume is reduced by one-half. Determine the work done and the heat transfer for this process.

Known: $m = 2.2 \text{ kg}$, $P_1 = 100 \text{ kPa}$, $T_1 = 25^\circ\text{C}$

Find: The work and heat transfer

10/10

Schematic: None

Assumptions: The process is constant or $P_1V_1^n = P_2V_2^n$.

Properties: All properties are known.

Analysis:

Equation: Use the work formula for an polytropic process to find the work and then use the work found to find the heat transfer. However, for the work formula rewrite PV as $mR(\Delta T)$ and in order to do that we need to find T_2 . We find T_2 by using $(P_2V_2)/T_2 = (P_1V_1)/T_1$. Use the formula $P_1V_1^n = P_2V_2^n$, to find P_2

Solution:

$$P_2V_2^{1.3} = P_1V_1^{1.3}$$

$$P_2 = P_1(V_1/V_2)^{1.3}$$

$$P_2 = (100)(2)^{1.3}$$

$$P_2 = 246 \text{ kPa}$$

$$(P_2V_2)/T_2 = (P_1V_1)/T_1$$

$$T_2 = (P_2V_2T_1)/(P_1V_1)$$

$$T_2 = (246 \text{ kPa} \times 298 \text{ K}) / (2 \times 100 \text{ kPa})$$

$$T_2 = 366.9 \text{ K}$$

$$W(\text{in}) = (mR(T_2 - T_1)) / (1 - n)$$

$$W(\text{in}) = (2.2 \text{ kg})(2968)(366.9 \text{ K} - 298 \text{ K}) / (1 - 1.3)$$

$$W(\text{in}) = 149.9 \text{ kJ}$$

$$W(\text{in}) - Q(\text{out}) = mC_v(T_2 - T_1)$$

$$Q(\text{out}) = mC_v(T_2 - T_1) - W(\text{in})$$

$$Q(\text{out}) = (2.2 \text{ kg})(.749)(366.9 \text{ K} - 298 \text{ K}) - 149.9 \text{ kJ}$$

$$Q(\text{out}) = 37.2 \text{ kJ}$$

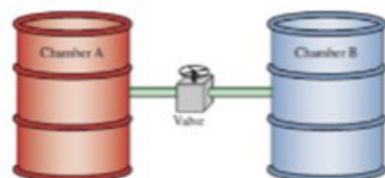
Problem 4-137

Two adiabatic chambers, 2 m³ each, are interconnected by a valve, as shown in Fig. P4-137, with one chamber containing oxygen at 1000 kPa and 127°C and the other chamber evacuated. The valve is now opened until the oxygen fills both chambers and both tanks have the same pressure. Determine the total internal energy change and the final pressure in the tanks.

Known: $P(\text{chamber A}) = 1000 \text{ kPa}$, $T(\text{Chamber A}) = 127^\circ\text{C}$, $V = 2 \text{ m}^3$

Find: The total internal energy change and the final pressure in the tanks.

Schematic:



10/10

Assumptions: The process is some kind of form of mechanical energy

Properties: All properties are known

Analysis:

In this process it is a form of mechanical energy and there is no statement for some form of Kinetic and potential energy change, so the internal energy change is $\Delta U = 0$. To find the final pressure use $P_2 V_2 = P_1 V_1$

Equation:

$$P_2 V_2 = P_1 V_1$$

$$P_2 = P_1 (V_1 / V_2)$$

$$P_2 = 1000 \text{ kPa} (2 \text{ m}^3 / 4 \text{ m}^3)$$

$$P_2 = 500 \text{ Kpa}$$

$$V_2 = (2 + 2) \text{ m}^3$$

$$V_2 = 4 \text{ m}^3$$

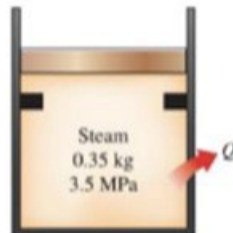
Problem 4-141 (A)

A piston-cylinder device initially contains 0.35 kg of steam at 3.5 MPa, superheated by 7.4°C. Now the steam loses heat to the surroundings and the piston moves down, hitting a set of stops at which point the cylinder contains saturated liquid water. The cooling continues until the cylinder contains water at 200°C. Determine (a) the final pressure and the quality (if mixture), (b) the boundary work, (c) the amount of heat transfer when the piston first hits the stops, and (d) the total heat transfer.

Known: $m = 0.35 \text{ kg}$, $P_1 = 3.5 \text{ MPa} \Rightarrow 3500 \text{ kPa}$, $T(i) = 7.4^\circ\text{C}$, $T(f) = 200^\circ\text{C}$

Find: The final pressure and the quality of the mixture

Schematic:



Assumptions: The temperature for the steam is not the same as the temperature for when it is a saturated liquid, so we need to convert the temperature for the steam to a mixture to get a more accurate value. We also use the final temperature to find the v_2 for saturated liquid, and the temperature found (T_1) to find v_1 . The pressure throughout the process also remains constant.

Properties: All properties are known

Analysis:

Use the final temperature ($T(f)$) to find the final pressure from the saturated mixture table for water.

$$P(\text{sat}) = 1554.9 \text{ kPa}$$

Find the quality by finding the initial temperature first.

$$T_1 = T(\text{sat}) + 7.4^\circ\text{C}$$

$$T_1 = (242.6 + 7.4)^\circ\text{C} = 250^\circ\text{C}$$

$$\text{so, } v_1 = 0.05876 \text{ m}^3/\text{kg} \text{ \& } v_2 = 0.001235$$

$$v_2 = v_3$$

$$\text{so, } v_2 = v(f@200^\circ\text{C}) + x_3 v(fg@200^\circ\text{C})$$

$$0.001235 = 0.001157 + x_3(0.1261)$$

$$x_3 = (0.001235 - 0.001157)/(0.126053)$$

$$x_3 = 0.062\%$$



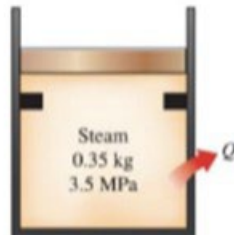
Problem 4-141 (B)

A piston-cylinder device initially contains 0.35 kg of steam at 3.5 MPa, superheated by 7.4°C. Now the steam loses heat to the surroundings and the piston moves down, hitting a set of stops at which point the cylinder contains saturated liquid water. The cooling continues until the cylinder contains water at 200°C. Determine (a) the final pressure and the quality (if mixture), (b) the boundary work, (c) the amount of heat transfer when the piston first hits the stops, and (d) the total heat transfer.

Known: $m = 0.35 \text{ kg}$, $P_1 = 3.5 \text{ MPa} \Rightarrow 3500 \text{ kPa}$, $T(i) = 7.4^\circ\text{C}$, $T(f) = 200^\circ\text{C}$

Find: The work boundary

Schematic:



Assumptions: Not too much work to do since all the values we need to find the work we have already found in the previous problem

Properties: All properties are given

Analysis: Use the work formula for constant pressure to find the work boundary. ✓

$$W_b = mP(v_2 - v_1)$$

$$W_b = (0.35 \text{ kg} \times 3500 \text{ kPa})(0.001235 - 0.05876) \text{ (m}^3/\text{kg)}$$

$$W_b = -70.468125 \text{ kJ}$$

Comments: Notice the work boundary is negative its because there is work leaving the system as the piston is cooling

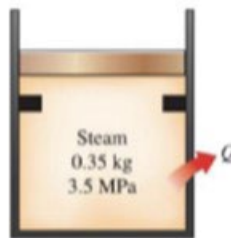
Problem 4-141 (C)

A piston-cylinder device initially contains 0.35 kg of steam at 3.5 MPa, superheated by 7.4°C. Now the steam loses heat to the surroundings and the piston moves down, hitting a set of stops at which point the cylinder contains saturated liquid water. The cooling continues until the cylinder contains water at 200°C. Determine (a) the final pressure and the quality (if mixture), (b) the boundary work, (c) the amount of heat transfer when the piston first hits the stops, and (d) the total heat transfer.

Known: $m = 0.35 \text{ kg}$, $P_1 = 3.5 \text{ MPa} \Rightarrow 3500 \text{ kPa}$, $T(i) = 7.4^\circ\text{C}$, $T(f) = 200^\circ\text{C}$

Find: The amount of heat transfer

Schematic:



10/10

Assumptions: To find the heat transfer first we need to find h_1 and h_2 , we can do that by finding them the same way we found v_1 and v_2 . h_1 is found from the T_1 state ($h_f@250^\circ\text{C}$) and h_2 is given by the pressure at 3500 kPa. After that we then plug the values we found into the heat transfer formula.

Properties: All properties are known

Analysis: Use the heat transfer formula to find the heat transfer

$$Q(12) = m(h_2 - h_1) \quad , \quad h_1 = 2829.7 \text{ kJ/kg} \cdot \text{K} \text{ \& } h_2 = 1049.7 \text{ kJ/kg} \cdot \text{K}$$

$$Q(12) = (0.35 \text{ kg})(1049.7 - 2829.7)(\text{kJ/kg} \cdot \text{K})$$

$$Q(12) = -623 \text{ kJ}$$

Comments: Notice the energy is negative, because heat is leaving the piston making the value negative.

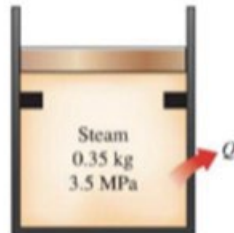
PROBLEM 4-141 (D)

A piston-cylinder device initially contains 0.35 kg of steam at 3.5 MPa, superheated by 7.4°C. Now the steam loses heat to the surroundings and the piston moves down, hitting a set of stops at which point the cylinder contains saturated liquid water. The cooling continues until the cylinder contains water at 200°C. Determine (a) the final pressure and the quality (if mixture), (b) the boundary work, (c) the amount of heat transfer when the piston first hits the stops, and (d) the total heat transfer.

Known: $m = .35 \text{ kg}$, $P_1 = 3.5 \text{ MPa} \Rightarrow 3500 \text{ kPa}$, $T(i) = 7.4^\circ\text{C}$, $T(f) = 200^\circ\text{C}$

Find: The Total amount of heat transfer

Schematic:



Assumption: Note that the question states that the piston moves down as it cools and turns in a saturated mix. In part C of the question we found the heat transfer of this reaction for when the piston stops. This is not the total amount of heat transfer. To find the total we need to add the heat transfer for when the piston stops and the heat transfer for when it cools.

Properties: All properties are known

Analysis: In order to find the total heat transfer, we first need to find the entropy ($h(\text{avg})$) for when it is cooling after it becomes a liquid. We do this by using the $h(\text{avg})$ formula.

$$h(\text{avg}) = h(f@200^\circ\text{C}) + x_3 h(fg@200^\circ\text{C})$$

$$h(\text{avg}) = 852.26 \text{ kJ/kg} + (.00062)(1938.8 \text{ kJ/kg})$$

$$h(\text{avg}) = 853.462 \text{ kJ/kg} = h_3$$

Take h_3 and plug it into the heat transfer for $Q(23)$ and then add $Q(12)$ together to get the total heat transfer.

$$Q(23) = m(h_3 - h_1) \Rightarrow (.35 \text{ kg})(853.462 - 1049.7) \text{ kJ/kg} = -68.6833 \text{ kJ/kg}$$

$$Q(13) = Q(12) + Q(23) \Rightarrow -623 \text{ kJ/kg} + (-68.6833 \text{ kJ/kg}) = -691.6833 \text{ kJ/kg}$$

Known: $P_1 = 40 \text{ psia}$, $T_1 = 600^\circ\text{F}$, $m = 1 \text{ lbm}$, condensation = 70%.

Find: Determine the work done during this process

Schematic: N/A

Show process on a diagram

Assumptions: The steam tables for superheated water will be needed to find the specific volume to solve the problem

Properties: We can find the specific volume at 40 psia by using the saturated pressure tables

Analysis: v_1 at 40 psia and 600°F $\rightarrow$ ~~15.636~~ 15.686 ft³/lbm

$$x = 100\% - 70\% = 30\% = 0.3 \quad 10/10$$

$$v_2 = v_f + x_2 v_g = 0.01715 + (0.3)(10.501 - 0.01715) = 3.1623 \text{ ft}^3/\text{lbm}$$

$v_f = 0.01715$
 $v_g = 10.501$

$$W = \int_1^2 P dv = P(v_2 - v_1) = mP(v_2 - v_1)$$

$$= (1)(70)(3.1623 - 15.686) \left(\frac{1 \text{ Btu}}{5.4039} \right)$$

$$= -1483 \text{ Btu}$$

-1483 Btu

AVERAGE

Known: $P_1 = 40 \text{ psia}$, $T_1 = 600^\circ\text{F}$, $m = 1 \text{ lbm}$, condensation = 70%.

Find: Determine the work done during this process

Schematic: N/A

Show process on a diagram

Assumptions: The steam tables for superheated water will be needed to find the specific volume to solve the problem

Properties: We can find the specific volume at 40 psia by using the saturated pressure tables

Analysis: v_1 at 40 psia and 600°F $\rightarrow$ ~~15.636~~ 15.686 ft³/lbm

$$x = 100\% - 70\% = 30\% = 0.3 \quad 10/10$$

$$v_2 = v_f + x_2 v_g = 0.01715 + (0.3)(10.501 - 0.01715) = 3.1623 \text{ ft}^3/\text{lbm}$$

$v_f = 0.01715$
 $v_g = 10.501$

$$W = \int_1^2 P dv = P(v_2 - v_1) = mP(v_2 - v_1)$$

$$= (1)(70)(3.1623 - 15.686) \left(\frac{1 \text{ Btu}}{5.4039} \right)$$

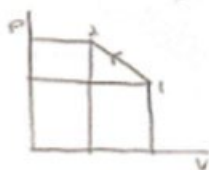
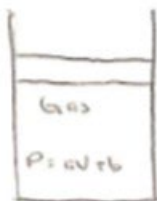
$$= -1483 \text{ Btu}$$

-1483 Btu

Known: $V_1 = 0.42$, $V_2 = 0.12$, $a = -1200$, $b = 600$

Find: Calculate the work done during this process, a) by plotting the process on a P-V diagram and finding the area under the process curve and b) by performing the numerical integration.

Sketches:



Assumptions: The following equation, $P = aV + b$, will be used to solve the problem. We will also need to find the work in both parts.

Preparation: $P_1 = aV_1 + b$

$$= -1200(0.42) + 600 = 96 \text{ kPa} \quad \underline{96 \text{ kPa}}$$

$$P_2 = aV_2 + b = -1200(0.12) + 600 = 456 \text{ kPa} \quad \underline{456 \text{ kPa}}$$

$$\begin{aligned} \text{a). } W &= \frac{1}{2}(V_2 - V_1)(P_2 - P_1) + (V_1 - V_2)P_1 \\ &= \frac{1}{2}(0.12 - 0.42)(456 - 96) + (0.42 - 0.12)96 \\ &= -82.8 \text{ J} \quad \underline{-82.8 \text{ kJ}} \end{aligned}$$

10/10

$$\begin{aligned} \text{b). } W &= \int_{V_1}^{V_2} P dV = \int_{0.42}^{0.12} (aV + b) dV = \int_{0.42}^{0.12} (-1200V + 600) dV \\ &= \left(-1200 \frac{V^2}{2} + 600V \right) \Big|_{0.42}^{0.12} \\ &= \left(-1200 \frac{(0.12)^2}{2} + 600(0.12) \right) - \left(-1200 \frac{(0.42)^2}{2} + 600(0.42) \right) \\ &= -82.8 \text{ J} \quad \underline{-82.8 \text{ kJ}} \end{aligned}$$

Nogh Smith

4.15 Problem 4.15

known:

gas expands: 350 kPa

initial volume: 0.03 m^3

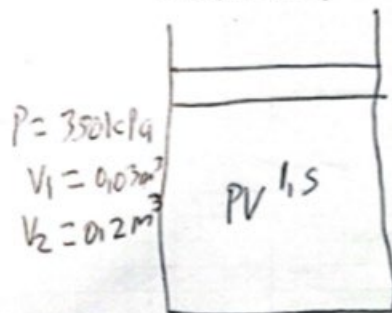
final volume: 0.2 m^3

$n = 1.5$

Find:

Calculate the work done when
a gas expands.

Conditions are constant
schematic:



Assumptions:

n , C , and P will not
change but the volume will and so
will pressure

equations:

$$P_1 V_1^n = P_2 V_2^n$$

$$\frac{350 \text{ kPa} \times (0.103 \text{ m}^3)^{1.5}}{(0.2 \text{ m}^3)^{1.5}} = \frac{P_2 \times (0.2 \text{ m}^3)^{1.5}}{(0.2 \text{ m}^3)^{1.5}}$$

$$P_2 = 20.33 \text{ kPa}$$

work done

$$w = \frac{P_1 V_1 - P_2 V_2}{n-1}$$

Not the standard form of equation

$$w = \frac{350 \times 0.103 - 20.33 \times 0.2}{1.5 - 1}$$

$$w = \frac{10.15 - 4.066}{0.5}$$

$$w = \frac{6.434}{0.5}$$

9/10

$$w = \boxed{12.868 \text{ kJ}}$$

Noah Smith

Problem # 4.20

known:

air initially: 0.15 kg $C = 623\text{K}$

2 MPa

350°C

expanded - 500 kPa

1.2 initial pressure

Find:

Determine the boundary work for each process and the net work of the cycle.

schematic:



assumptions:

1. isothermally first - temperature held constant
2. compressed polytropically - $PV^n = C$
3. Finally constant pressure - isobaric equations:

Ideal gas: $V_1 = \frac{mRT_1}{P_1}$

$$= \frac{0.15 \times 2869 \times 623}{2 \times 10^6} = \boxed{0.0134\text{m}^3}$$

Is other mal - $\left(\frac{P_1}{P_2}\right) \times V_1$
process

$$V_2 = \left(\frac{2}{0.5}\right) \times 0.0139 = 0.0536 \text{ m}^3$$

Polytropic process - $\left(\frac{P_2}{P_3}\right)^{1/k} \times V_2$

$$V_3 = \left(\frac{0.5}{2}\right)^{1/1.2} \times 0.0536 \text{ m}^3$$

$$V_3 = 0.0169 \text{ m}^3$$

1. isothermal expansion: $w_{12} = mRT \ln \frac{P_1}{P_2}$

$$10/10 \quad w_{12} = 0.15 \times 286.9 \times 6.23 \times \ln\left(\frac{2}{0.5}\right)$$

$$w_{12} = 37167.67 \text{ J}$$

$$= \boxed{37.168 \text{ kJ}}$$

2. Polytropic expansion:

$$w_{23} = \frac{P_3 V_3 - P_2 V_2}{1 - k}$$

$$w_{2-3} = \frac{(2 \times 10^6 \times 0.0169) - (500 \times 10^3 \times 0.0536)}{1 - 1.2}$$

$$w_{2-3} = -35000 \text{ J} \rightarrow \boxed{-35 \text{ kJ}}$$

3. Isobaric compression;

$$w_{3-4} = P_3 (V_4 - V_3)$$

$$w_{3-4} = 2 \times 10^6 (0.0139 - 0.0169)$$

$$w_{3-4} = -7000 \text{ J} \Rightarrow \boxed{-7 \text{ kJ}}$$

work done by gas from all processes
and compression/expansions:

$$w_{\text{all}} = w_{1-2} + w_{2-3} + w_{3-4}$$

$$= 37.168 - 35 - 7$$

$$\boxed{w_{\text{all}} = -4.832 \text{ kJ}}$$



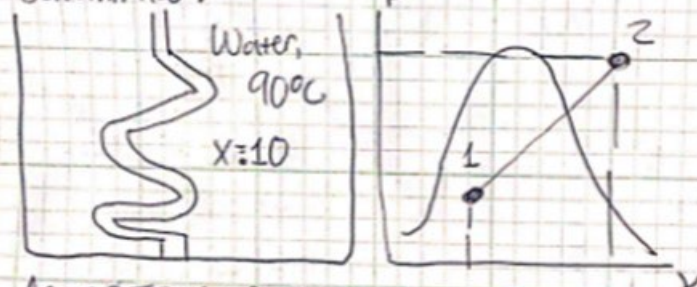
PROBLEMS: 4-22

KNOWN: 1 kg of Water = Mass, $T = 90^\circ\text{C}$ INITIAL,
 PRESSURE, FINAL = 800 kPa, FINAL TEMPERATURE: 250°C

FIND: Work

Unreadable

SCHEMATIC:



ASSUMPTIONS: CONDITIONS ARE IDEAL
 PROPERTIES, H_2O at 90°C , Quality = 10%

ASSUMPTIONS: THE PROBLEM IS IN QUASI-EQUILIBRIUM
 ANALYSIS: $P_1 = 170.183 \text{ kPa}$

$$v_1 = v_f + x v_{fg} = 0.001036 + (0.10)(2.3595 - 0.001036)$$

$$= 0.23686 \text{ m}^3/\text{kg}$$

IN TABLE A6

$$v_2 = 0.29321 \text{ m}^3/\text{kg} \quad (800 \text{ kPa})(250^\circ\text{C})$$

$$W_{10, \text{out}} = \text{Area or } \frac{P_1 + P_2}{2} m(v_2 - v_1)$$

$$= \frac{(170.183 + 800) \text{ kPa}}{2} (1 \text{ kg})(0.29321 - 0.23686) \text{ m}^3 \left(\frac{1 \text{ kJ}}{1 \text{ kPa} \cdot \text{m}^3} \right)$$

$$= \sqrt{2.4.52 \text{ kJ}} \quad \boxed{24.52 \text{ kJ}}$$

4-29 Complete each line on the following table.

Q_{in} kJ	W_{out} kJ	E_1 kJ	E_2 kJ	m kg	$e_2 - e_1$ kJ/kg
280	440	1020	860	3	-53.33
-350	130	550	70	5	-96
-40	260	300		2	-150
300	550	750	500	1	-250
	-200	500	300	2	-100

Equation used: $Q_{in} + W_{in} - (Q_{out} + W_{out})$

$$E_2 - E_1 = m(e_2 - e_1)$$

Known: $P = 11 \text{ psia}$, $T_1 = 10^\circ\text{F}$, $T_2 = 200^\circ\text{F}$

Find: Determine the work and heat transfer associated with this process in Btu/lbm

Schematic: N/A

Assumptions: The ideal gas equation will be needed to solve for a constant pressure.

10/10

Properties: The problem is isobaric, so the pressure will remain constant. $P_1 = P_2$

Analysis: $\text{O}_2 = M = 0.0453$, $c_p = 0.155$

$$W = P(v_2 - v_1) = m(T_2 - T_1) = 0.0453(200 - 10) = 5.42 \text{ Btu/lbm}$$

$$q = c_v(T_2 - T_1) + W = 0.155(200 - 10) + 5.42 = 24.4 \text{ Btu/lbm}$$

4.74 Problem #4.74

Known:

2, 2 kg - Nitrogen

100 kPa - Initially

25°C - Initially

$$PV^{1.3} = \text{constant}$$

Find:

determine the work done and heat transfer for this process.

Assumption:

Since it is a polytropic process the PV^n will be constant;

equations:

$$P_2 = P_1 \left(\frac{V_1}{V_2} \right)^{1.3}$$

$$P_2 = (100 \text{ kPa}) (2)^{1.3}$$

$$= 246.2 \text{ kPa}$$

$$T_1 = 25^\circ\text{C}$$

$$= (273 + 25) \text{ K}$$

$$= 298 \text{ K}$$

$$T_2 = \frac{(T_1)(298 \text{ K})}{2(100 \text{ kPa})} = \frac{(246.2 \text{ kPa})(298 \text{ K})}{2(100 \text{ kPa})}$$

$$W_{bin} = \frac{mRT_2 - mRT_1}{1 - \eta}$$

$$= \frac{-mR(T_2 - T_1)}{1 - \eta}$$

$$= \frac{-(2.2 \text{ kg})(0.2968 \text{ kJ/kg}\cdot\text{K})(366.9 \text{ K} - 298 \text{ K})}{1 - 1.3}$$

$$= \boxed{149.9 \text{ kJ}} \quad \checkmark$$

$$149.9 \text{ kJ} - Q_{out} = (2.2 \text{ kg})(0.744 \text{ kJ})(366.9 - 298)$$

$$= \boxed{37.2 \text{ kJ}} \quad \checkmark$$

4.137 Problem #4.137

known:

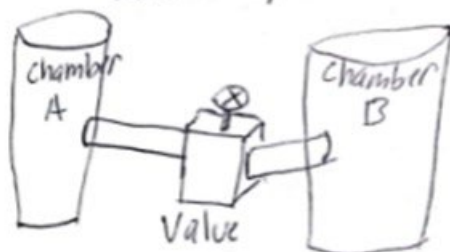
chambers - 2m^3

one chamber - oxygen - 1000kPa

-127°C

second chamber - evacuated

Schematics:



Find:

Determine the total internal energy change and the final pressure in the tanks.

Assumptions:

since the pressure and temperature is oxygen the internal energy is 0, change

equations:

$$V_2 = 2 + 2 = 4\text{m}^3$$

$$P_2 = P_1 \left(\frac{V_1}{V_2} \right)$$

$$P_2 = 1000 \left(\frac{2}{4} \right)$$

$$= 500\text{kPa}$$

4.141 Problem #4.141

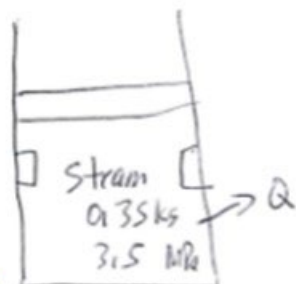
known:

Initially: 0.35 kg
 3.5 MPa

superheated: 7.4°C

water: 200°C

schematic



10/10

Find:

a) The final pressure and quality

b) boundary work

c) amount of heat transfer when the piston first hits the stops,

d) total heat transfer

Assumptions:

Finding three V_s is required

Equations:

$$P_1 = 3,5 \text{ MPa}$$

$$T_1 = 292,56^\circ\text{C}$$

$$T_1 = 292,56^\circ\text{C} + 7,4^\circ\text{C}$$
$$= 299,96^\circ\text{C}$$

$$V_1 = 0,05706 + \frac{(299,96 - 292,56)(0,05876 - 0,0526)}{(250 - 292,56)}$$

$$V_1 = 0,05875 \text{ m}^3/\text{kg}$$

$$V_3 = V_2 = 0,001235 \text{ m}^3/\text{kg}$$

$$x_3 = \frac{0,001235 - 0,001157}{0,12721 - 0,001157}$$

$$x_3 = 0,000618$$

$$U_3 = U_f + x_3 U_g$$

$$U_3 = 850,46 + (0,000618)(1793,7)$$

$$U_3 = 851,537 \text{ kJ/kg}$$

$$P_{out} = 1554,9 \text{ kPa}$$

$$P_3 = P_{out}$$

$$= 1554,9 \text{ kPa}$$

$$b.) w_{bin} = (0,35)(3500)(0,05875 - 0,001235) \\ = 70,45 \text{ kJ}$$

$$c.) \dot{Q}_{out 1-2} = 70,45 - (0,35(1045,4 - 2623,9)) \\ = 622,925 \text{ kJ/kg}$$

D. Total heat transfer

$$\dot{Q}_{out 1-3} = 70,45 - (0,35(851,537 - 2623,9)) \\ = 690,777 \text{ kJ}$$

THERMODYNAMICS I
FALL 2021

HOMEWORK 5

TOPICS COVERED IN HOMEWORK 5

Mass and Energy Analysis of Control Volumes

HOMEWORK #5 QUESTIONS

Problems [5.6 a, b, c, (d) calculate the heat transferred to the air, Q , in kW], 5.11, 5.33, 5.48, 5.52, 5.57, 5.64, 5.74, 5.81, 5.116, 5.183

ABOVE AVERAGE

5-6 GIVEN: $D = 16 \text{ cm}$, $P_i = 200 \text{ kPa}$, $T_i = 20^\circ \text{C}$
 $P_e = 120 \text{ kPa}$, $T_e = 40^\circ \text{C}$

97.5/110 = 89%

FIND: a.) Volumetric flow rate

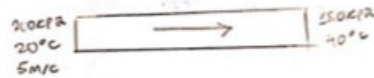
b.) mass flow rate

c.) velocity of volume flow rate

d.) heat transferred

$$A_{\text{th}} = \frac{\pi (0.16)^2}{4} = 0.020106 \text{ m}^2$$

SCHEMATIC:



5/10

a.) Vol flow rate = $A \cdot V = 0.40053 \text{ m}^3/\text{s}$?

b.) mass flow rate = $\rho_i \cdot P_{\text{air}}$

$$\rho_{\text{air}} = \frac{P}{T_{\text{ref}}} = \frac{200 \times 10^3}{287.05 \times 293} = 2.5179 \text{ kg/m}^3$$

$$2.5179 \text{ kg/m}^3 \times 0.40053 \text{ m}^3/\text{s} = 0.25905 \text{ kg/s}$$

c.) velocity of flow rate @ exit

$$\rho_{\text{air exit}} = \frac{120 \times 10^3}{287.05 \times 313} = 2.0036 \text{ kg/m}^3$$

$$2.0036 \text{ kg/m}^3 \times V_{\text{exit}} = 0.25905 \text{ kg/s}$$

$$V_{\text{exit}} = \frac{0.25905 \text{ kg/s}}{2.0036 \text{ kg/m}^3} = 0.3651 \text{ m/s}$$

$$V_{\text{exit}} = 0.3651 \text{ m/s} \times 0.020106 \text{ m}^2 = 18.17 \text{ m}^3/\text{s}$$

5-6 (cont.)

$$d.) \text{ heat transferred to air} = P_{\text{ini}} - P_{\text{final}}$$

$$= 200 \text{ kPa} - 180 \text{ kPa}$$

$$= \boxed{20 \text{ kPa}}$$

November 11, 2021 / Homework #5 #5.11 / Jeremy Bating

Given: Volume: 2 m^3

Density: $\frac{\text{mass}}{\text{Volume}}$

Volume: $\frac{\text{mass}}{\text{density}}$

$$\text{mass} = \text{Density} \times \text{Volume}$$

Use format

$$\text{initial mass} = 1.18 \times 2$$

$$m_1 = 2.36\text{ kg}$$

$$\text{Final mass } m_2 = 5.30 \times 2$$

$$V_1 = V_2 = 2\text{ m}^3$$

$$m_2 = 10.6\text{ kg}$$

9/10

$$\text{Mass entered } \Delta m = m_2 - m_1 \quad \Delta m = 10.6 - 2.366$$

$$\Delta m = 8.24\text{ kg}$$

November 11, 2021 | Homework 5 # 5.33 | Jeremy Baird

Given: Steam enters in nozzle,

Velocity of the steam = 10 m/s v_1 Inlet temperature = 400°C T_1

The outlet temperature = 375°C T_2 Inlet Pressure = 1000 kPa P_1

The outlet pressure = 400 kPa P_2

Losing heat at a rate of = 25 kW $\Rightarrow Q = -25$



Supersaturated heat steam tables

$$v_1 = 0.38429 \text{ m}^3/\text{kg}, \quad h_1 = 3267.7 \text{ kJ/kg}$$

Outlet of P_2, T_2 superheated steam table

$$v_2 = 0.74332 \text{ m}^3, \quad h_2 = 3221.8$$

Find volume of steam @ nozzle exit

Energy balance equation:

$$(q - w) \cdot (h_2 - h_1) + \frac{(v_2^2 - v_1^2)}{2} + g(z_2 - z_1)$$

$$q = (h_2 - h_1) + \frac{(v_2^2 - v_1^2)}{2}$$

$$\frac{Q}{m} = (h_2 - h_1) + \frac{(v_2^2 - v_1^2)}{2}$$

$$\frac{-25 \times 10^3}{(2.08)} = (3221.8 - 3267.7) \times 10^3 + \frac{(v_2^2 - (10)^2)}{2}$$

$$-12019.2307 = -45900 + \frac{(v_2^2 - 100)}{2}$$

$$-12019.2307 + 45900 = \frac{v_2^2 - 100}{2}$$

$$(33880.7693) = \frac{v_2^2 - 100}{2}$$

$$2(33880.7693) = v_2^2 - 100$$

$$67761.5386 + 100 = v_2^2$$

$$v_2^2 = \sqrt{67761.5386} \Rightarrow v_2 = 260.5024 \text{ m/s}$$

10/10

Mass flow:

$$m = \frac{(0.08)(10)}{(0.38429)}$$

$$= \frac{0.8}{0.38429} \quad m = 2.08769$$

November 11, 2021 | Homework 5 #5.33 | Jeremy Peters

Volume flow rate at exit of nozzle

$$(2.08) \times (0.743328)$$

$$= 1.546122$$

$$V_2 = 1.546 \text{ m}^3/\text{sec}$$

Noah Smith

S148

known!

inlet conditions

4 MPa, 500°C, 80 m/s

exit conditions

30 kPa, 92 percent quality

50 m/s

mass flow rate

12 kg/s

Find!

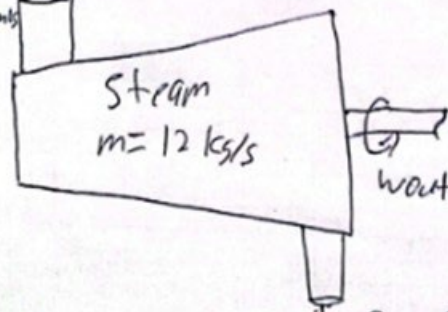
a) Determine the change in kinetic energy

b) The power output

c) turbine inlet Area

Schematic:

$P_1 = 4 \text{ MPa}$
 $T_1 = 500^\circ\text{C}$
 $V_1 = 80 \text{ m/s}$



$P_2 = 30 \text{ kPa}$
 $x_2 = 0.92$

Assumptions:

The energy balance equation and mass flow rate will be used,

equations:

$$\begin{aligned} a'. \Delta h E &= \frac{V_2^2 - V_1^2}{2} & 9.5/10 \\ &= \frac{(50)^2 - (80)^2}{2} \times \frac{1 \text{ kJ/kg}}{1000 \text{ m}^2/\text{s}^2} \\ &= \boxed{-1.95 \text{ kJ/kg}} \end{aligned}$$

$$b'. E_{in} = E_{out}$$

$$\dot{m} \left(h_1 + \frac{V_1^2}{2} \right) = \dot{W}_{out} + \dot{m} \left(h_2 + \frac{V_2^2}{2} \right)$$

$$P_1 = 9 \text{ MPa}$$

$$h_1 = 3446 \text{ kJ/kg}$$

$$T_1 = 500^\circ\text{C}$$

$$V_1 = 0.08699 \text{ m}^2/\text{s}$$

$$P_2 = 30 \text{ kPa}$$

$$h_2 = 2891.27 + 0.92(2335.3)$$

$$x_2 = 0.92$$

$$= 2937.796 \text{ kJ/kg}$$

$$\dot{W}_{out} = -\dot{m} \left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} \right]$$

$$\dot{W}_{out} = -12 [2937.796 - 3446 + (-1.95)]$$

$$\boxed{\dot{W}_{out} = 12.1}$$

Units?

$$C_i \quad m' = \frac{1}{V_i} A_i V_i \Rightarrow A_i \frac{m_i \times 0.08689}{N_i}$$

$$A_i = \frac{12 \times 0.08689}{80} \checkmark$$

$$= 0.0129$$

$$= \boxed{0.013 \text{ m}^2}$$

Nagh Smith

S152

known:

10 L/s

120 kPa

20°C

1000 kPa

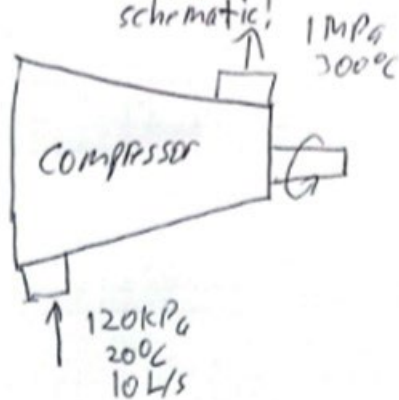
300°C

Find:

10/10

- a', Determine the work required by the compressor in kJ/s
- b', The power required to drive the air compressor, in kW.

schematic:



~~Assumptions:~~

equations:

$$E_{in} = E_{out}$$

$$W_{in} + \left(h_1 + \frac{C_1^2}{2} + s_{21} \right) + Q_{in} = \left(h_2 + \frac{C_2^2}{2} + s_{22} \right) + W_{out} + Q_{out}$$

$$W_{in} = h_2 - h_1$$

a.

$$T_2 = 300^\circ\text{C} + 273 = 573\text{K}$$

$$T_1 = 20^\circ\text{C} + 273 = 293\text{K}$$

$$T = 290\text{K} \rightarrow h = 290,16 \text{ kJ/kg}$$

$$T' = 295\text{K} \rightarrow h' = 295,17 \text{ kJ/kg}$$

$$T_1 = 293\text{K} \rightarrow h = ?$$

$$\frac{T_1 - T'}{T - T'} = \frac{h_1 - h'}{h - h'} = \frac{293 - 295}{290 - 295} = \frac{h_1 - 295,17}{290,16 - 295,17}$$

$$= 293,166 \text{ kJ/kg}$$

$$T_2 = 573\text{K} \rightarrow h = ?$$

$$T = 570\text{K} \rightarrow h = 575,59$$

??

$$T' = 580\text{K} \rightarrow h' = 586,09$$

$$\frac{T_2 - T'}{T - T'} = \frac{h_2 - h'}{h - h'} = \frac{573 - 580}{570 - 580} = \frac{h_2 - 586,09}{575,59 - 586,09}$$

$$h_2 = 578,725 \frac{\text{kJ}}{\text{kg}}$$

$$W_{in} (578,725 - 293,166) = \boxed{285,559 \text{ kJ/kg}}$$

$$b_1 \quad \dot{w} = \dot{m} \text{ (kg/s)} \times w_{in} \text{ (kJ/kg)} \quad \text{ideal gas} \\ = \frac{P_1 V_1}{RT_1} \times w_{in} \quad \dot{m} = \frac{P_1 V_1}{RT_1}$$

$$= \frac{120 \text{ kPa} \times 10 \times 10^{-3} \text{ m}^3/\text{s}}{0.287 \times 293} \times 285.559$$

$$\dot{w} = \boxed{4.07 \text{ kW}} \quad \checkmark$$

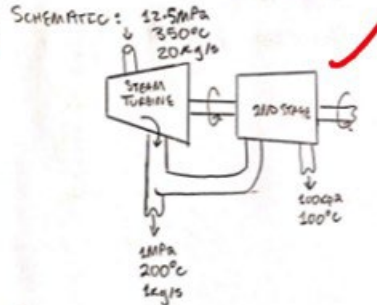
5-57

Given: $P_1 = 12.5 \text{ MPa}$, $T_1 = 550^\circ\text{C}$, $m_1 = 20 \text{ kg/s}$ | $C_{v1} = P_3 = 100 \text{ kPa}$
 $P_2 = 1000 \text{ kPa}$, $T_2 = 200^\circ\text{C}$, $m_2 = 1 \text{ kg/s}$ | $T_3 = 100^\circ\text{C}$

Find: Power produced, P in kW

$h = 2675.8 \text{ kJ/kg}$
 * ON WATER TABLE

10/10



ANALYSIS:

$$Q \cdot W = m \left(h_1 - h_2 + \frac{V_1^2 - V_2^2}{2} + g(z_1 - z_2) \right), \quad Q = 0, \quad P_2 \approx 0, \quad P_3 \approx 0$$

$$-W_1 = m(h_2 - h_1 + 0 + 0)$$

$$\Rightarrow W_1 = (h_1 - h_2) = 20(3476.5 - 2828.3) \text{ kJ/kg} = 12964 \text{ kW}$$

$$W_2 = m_3(h_2 - h_3) \Rightarrow m_3 = m_1 - m_2 = 20 - 1 = 19 \text{ kg/s}$$

5-57 (cont)

$$W_2 = m_3(h_2 - h_3) \checkmark$$

$$= 19(2828.3 - 2675.8)$$

$$= 2897.5 \text{ kW}$$

Leaving $W_{\text{TOTAL}} = W_1 + W_2$

$$= 12964 + 2897 \checkmark$$

$$= 15,861.5 \text{ kW} \approx \boxed{15,860 \text{ kW}}$$

Noah Smith

569

known!

50°C - saturated liquid

-20°C - leaves

Find!

quality of the refrigerant

Assumptions! 10/10

Refrigerant - 134a will be used

schematic!

None

equations!

$$T_1 = 50^{\circ}\text{C}$$

$$T_2 = -20^{\circ}\text{C}$$

$$h_1 = h_f = 123.5 \text{ kJ/kg}$$

$$h_f = 25.49 \text{ kJ/kg}$$

$$h_{fg} = 212.91 \text{ kJ/kg}$$

$$h_2 = h_f + x(h_{fg})$$

$$123.5 = (25.49) + x(212.91)$$

$$x = 0.46$$

5-74

Given: $T_1 = 80^\circ\text{C}$, $\dot{m}_1 = 0.5 \text{ kg/s}$, $T_2 = 20^\circ\text{C}$, $T_3 = 42^\circ\text{C}$
 $p = 250 \text{ kPa}$

Find: MASS FLOW RATE @ 250 kPa 10/10

$$\dot{m}_1 = \dot{m}_2 = \dot{m}_3, \dot{E}_1 = \dot{E}_2 = \dot{E}_3, \dot{m}_1 h_1 = \dot{m}_2 h_2 = \dot{m}_3 h_3$$

$$\dot{m}_1 + \dot{m}_2 = \dot{m}_3, \dot{m}_1 h_1 + \dot{m}_2 h_2 = (\dot{m}_1 + \dot{m}_2) h_3$$

$$\Rightarrow \dot{m}_2 = \frac{h_3 - h_1}{h_2 - h_3} \dot{m}_1$$

$$h_1 = h_f = 335.02 \text{ kJ/kg}, h_2 = h_g = 83.915 \text{ kJ/kg}$$

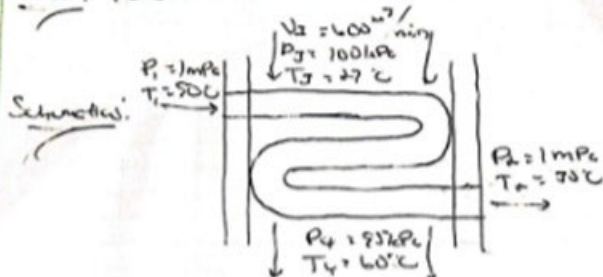
$$T_3 = 42^\circ\text{C}, h_3 = 167.53 + (188.44 - 167.53) \text{ kJ/kg} \left(\frac{42 - 40}{45 - 40} \right) \\ = 175.894 \text{ kJ/kg}$$

$$\dot{m}_2 = \frac{h_3 - h_1}{h_2 - h_3} \dot{m}_1 \Rightarrow \dot{m}_2 = \frac{175.894 - 335.02}{83.915 - 175.894} \times 0.5 \text{ kg/s} \\ = \boxed{0.865 \text{ kg/s}}$$

5-81

Known: $P_1 = 1 \text{ MPa}$, $P_3 = 100 \text{ kPa}$, $P_4 = 95 \text{ kPa}$, $T_1 = 90^\circ\text{C}$, $T_2 = 30^\circ\text{C}$,
 $T_3 = 27^\circ\text{C}$, $V = 600 \text{ m}^3/\text{min}$, $T_4 = 60^\circ\text{C}$, $P_2 = 1 \text{ MPa}$, $\Phi = 0.27$

Find: Determine the mass flow rate of the refrigerant



Assumptions: Values will need to be pulled from the air refrigerant tables. The energy balance equation will also need to be used.

7/10

Properties: P_1, P_3, T_1, T_3 and V_3 are entering the system while P_2, P_4, T_2 and T_4 are leaving.

Analysis: $P_1 = 1 \text{ MPa}$, $T_1 = 90^\circ\text{C}$, $h_1 = 324.66 \text{ kJ/kg}$

$P_2 = 1 \text{ MPa}$, $T_2 = 30^\circ\text{C}$, $h_2 = 93.58 \text{ kJ/kg}$

$$P_3 V_3 = m R T_3 = (100)(600) = m R (0.287)(27 + 273.15)$$

$$m = 696.52 \text{ kg}$$

$$E_{in} - E_{out} = E_2 - E_1$$

$$= m_1 h_1 + m c h_3 = m_2 h_2 + m c h_4 = 0$$

$$m = m c (h_4 - h_3) / (h_1 - h_2) = (m c) (C_p) (T_4 - T_3) / (h_1 - h_2)$$

$$= 696.52 (1.005) (60 - 27) / (324.66 - 93.58)$$

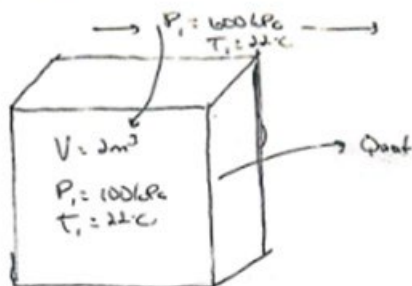
$$= 100 \text{ kg/min}$$

5-116

Known: $P_1 = 600 \text{ kPa}$, $T_1 = 22^\circ\text{C}$, $V = 2 \text{ m}^3$, $P_2 = 100 \text{ kPa}$, $T_2 = 77^\circ\text{C}$

Find: Determine a) the mass of air that has entered the tank and b) the amount of heat transfer.

Schematic:



Assumptions: The air property tables will need to be used to find the values of h .

Properties: P_1 and T_1 are leaving the system along with Q_{out}

Analysis: $T_1 = 22^\circ\text{C} + 273.15 = 295.15 \text{ K}$

10/10

$T_2 = 77^\circ\text{C} + 273.15 = 350.15 \text{ K}$

c)

$$m_1 = m_2 - m_i \rightarrow m_i = P_1 V / (R T_1) = (100)(2) / (0.287)(295.15)$$

$$m_2 = P_2 V / (R T_2) = (600)(2) / (0.287)(350.15) = 11.54$$

$$m_i = m_2 - m_1 = 11.54 - 2.36 = 9.18 \text{ kg}$$

9.58

b) $W = 0$

$$Q = -(m_2 - m_1)(h_1) + m_2 u_2 - m_1 u_1$$

$h_1 = 295.17 \text{ kJ/kg at } 22^\circ\text{C} = 295 \text{ kJ/kg}$

$u_2 = 250.02 \text{ kJ/kg at } 77^\circ\text{C} = 250 \text{ kJ/kg}$

$m_1 u_1 = 210.45$

$$Q = -(9.18)(295.17) + (11.54)(250.02)$$

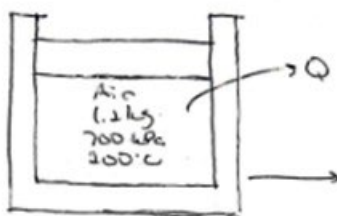
$$= -335 \text{ kJ}$$

-5.183

Known: $P_1 = 700 \text{ kPa}$, $T_1 = 200^\circ\text{C}$, $P_2 = 600 \text{ kPa}$, $Q = 40 \text{ kJ}$, $m = 1.2 \text{ kg}$

Find: Determine a) the final temperature of the air in the cylinder, b) the amount of mass that has escaped from the cylinder, and c) the work done.

Schematic:



Assumptions: The ideal gas equation as well as the mass balance equation will be needed to solve the problems.

Properties: The air property tables will be used to find the values of c_p and c_v .

Analysis: $P_1 = 700 \text{ kPa}$, $T_1 = 200^\circ\text{C}$, $c_v = 1.020$ and $c_p = 0.723$

$$T_2 = \frac{(T_1 + T_2)}{2} = \frac{(200 + 213.15 + T_2)}{2}$$

$$V_1 = m_1 R T_1 / P_1 = (1.2)(0.287)(200 + 273.15) / 700 = 0.2327 \text{ m}^3$$

$$V_2 = (0.002)(0.287) = 0.1862 \text{ m}^3$$

$$m_2 = P_2 V_2 / R T_2 = (600)(0.1862) / (0.287)(T_2) = 385.18 / T_2$$

$$W = P_2 (V_1 - V_2) = (600)(0.2327 - 0.1862) = \underline{27.545}$$

5-187

a)

$$E_{in} - E_{out} = \dot{E}_2 - \dot{E}_1$$

$$m_1 h_1 - m_2 h_2 = \Delta m$$

$$m_2 = m_1 - m_2 = \left(1.2 \left(\frac{325.15}{T_2} \right) \right)$$

$$W + Q = m_2 h_2 - m_1 h_1 = W + Q - m_1 c_p T_1 = m_2 c_p T_2 - m_1 c_p T_1$$

$$Q = 40$$

$$W = 27.5 \text{ kJ}$$

$$m_1 = \left(1.2 \left(\frac{325.15}{T_1} \right) \right)$$

$$c_p = 0.733$$

$$T_1 = \left(\frac{473.15 + T_2}{2} \right)$$

$$= 27.5 - 40 - \left(1.2 \cdot \frac{325.15}{T_2} \right) (0.733) \left(\frac{473 + T_2}{2} \right) =$$

$$\left(\frac{325.15}{T_2} \right) (0.733) T_2 - \left(1.2 \right) (0.733) (473)$$

$$T_2 = 415 \text{ K}$$

b)

$$m_2 = 1.2 - \left(\frac{325.15}{T_2} \right) = 1.2 - \left(\frac{325.15}{415} \right)$$

$$= 0.2022 \text{ kg}$$

Use format

7/10

AVERAGE

S-11

Temitayo Ojo

Christopher Scales

L.C. Houles Arrange work in numerical order of problem #

Keigan Kenney

Clayton Stribling

Problem Statement % A 2-m³ rigid tank initially contains air where density is 1.18 kg/m³. The tank is connected to a high-pressure supply line through a valve. The valve is opened, and air is allowed to enter the tank until the density in the tank rises to 5.30 kg/m³. Determine the mass of air that has entered the tank.

Known %density = 1.18 kg/m³ (initial)Volume = 2 m³ (~~initial~~)density = 5.30 kg/m³ (final)Find % Determine the mass of air that has entered the tank.Schematic % no sketch.assumptions % no assumptionsProperties % All need properties are known.Analysis %

Solution plan - ✓

$$m_{\text{final}} = 5.30 \times 2 = 10.6 \text{ kg}$$

$$\begin{aligned} &= m_{\text{final}} - m_{\text{initial}} \\ &= 10.6 - 2.36 \\ &= 8.24 \text{ kg} \end{aligned}$$

Comments % Use the right equation

5-33

Temitayo Ojo

Christopher Scates

L.C. Hollis

Keigan Kenney

Clayton Shubling

Problem Statement: Steam enters a nozzle at 400°C and 800 kPa with a velocity of 10 m/s , and leaves at 375°C and 400 kPa while losing heat at a rate of 25 kW . For an inlet area of 800 cm^2 , determine the velocity and the volume flow rate of the steam at the nozzle exit.

Known:

$$T_1 = 400^\circ\text{C}$$

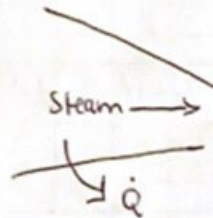
$$T_2 = 375^\circ\text{C}$$

$$P_1 = 800\text{ kPa}$$

$$P_2 = 400\text{ kPa}$$

$$\text{Velocity} = 10\text{ m/s}$$

Find: determine the velocity and the volume flow rate of the steam at the nozzle exit.

Schematic:assumptions: no assumptionsproperties: all needed properties are knownAnalysis:

Solution plan-

$$V_2 = 0.74321\text{ m}^3/\text{kg}$$

$$h_2 = 3222.2\text{ kJ/kg}$$

$$\dot{m} = \frac{A_1 V_1}{v_1} = \frac{(800 \times 10^{-4}) (10)}{0.38429}$$

$$\dot{m} = 2.0817612\text{ kg/s}$$

$$\dot{Q} - \dot{W} = \dot{m} \left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} \right]$$

$$\Rightarrow -25 \times 10^3 - 0 = 2.0817612 \left[(3222.2 \times 10^3 - 3267.7 \times 10^3) + \frac{V_2^2 - 10^2}{2} \right]$$

$$\Rightarrow V_2 = 259\text{ m/s}$$

$$\approx 260\text{ m/s}$$

$$\dot{m} = \frac{A_2 V_2}{v_2} = \frac{V_2}{v_2}$$

$$\Rightarrow 2.0817612 = \frac{V_2}{0.74321}$$

$$V_2 = 1.55\text{ m}^3/\text{s}$$

Comments: use the right formula.

5-48

Temitayo Ojo

Christopher Scales

L.C. Hollies
Kelgan Kemus
Clayton Striding

Problem Statement: Steam flows steadily through an adiabatic turbine. The inlet conditions of the steam are 4 MPa, 500°C, and 80 m/s, and the exit conditions are 30 kPa, 92 percent quality, and 50 m/s. The mass flow rate of the steam is 12 kg/s.

Known:

$$P_1 = 4 \text{ MPa}$$

$$T_1 = 500^\circ\text{C}$$

$$V_1 = 80 \text{ m/s}$$

$$\dot{m} = 12 \text{ kg/s}$$

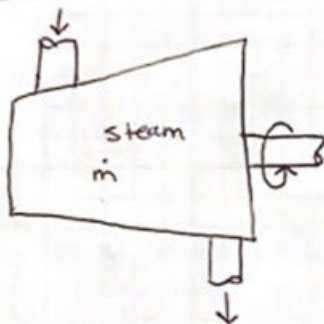
$$P_2 = 30 \text{ kPa}$$

$$x_2 = 0.92$$

$$V_2 = 50 \text{ m/s}$$

Find:

Determine the change in kinetic energy, the power output, and the turbine inlet area.

Schematic:assumptions:

no assumptions

Properties: All needed properties are known.Analysis:Equation $\dot{m} A V$

$$\Delta KE = \frac{V_2^2}{2} - \frac{V_1^2}{2}$$

$$E_{in} = E_{out}$$

$$\dot{m} = \frac{1}{V_1} A_1 V_1$$

$$\dot{m} \left(h_1 + \frac{V_1^2}{2} \right) = W_{out} + \dot{m} \left(h_2 + \frac{V_2^2}{2} \right)$$

Solution Plan -

$$\frac{(50)^2 - (80)^2}{2} \times \frac{1 \text{ kJ/kg}}{(1000 \text{ m/s})^2}$$

$$\Delta KE = -1.95 \text{ kJ/kg}$$

$$\left. \begin{array}{l} P_1 = 4 \text{ MPa} \\ T_1 = 500^\circ\text{C} \end{array} \right\} \begin{array}{l} h_1 = 3446 \text{ kJ/kg} \\ v_1 = 0.08644 \text{ m}^3/\text{kg} \end{array}$$

$$\left. \begin{array}{l} P_2 = 30 \text{ kPa} \\ x_2 = 0.92 \end{array} \right\} \begin{array}{l} h_2 = 289.27 + 0.92(2335.3) \\ = 2437.746 \text{ kJ/kg} \\ = -12[2437.746 - 3446 + (-1.95)] \end{array}$$

$$\dot{m} = \frac{1}{V_1} A_1 V_1$$

$$A_1 = \frac{12 \times 0.08644}{80} = 0.012966 \approx 0.013 \text{ m}^2$$

$$W_{out} = 12.1245 \text{ MW}$$

Comments: Find the enthalpy in the tables and use the right formula to find the rest missing.

5-52

Temitayo Ojo

Christopher scales

L.C. Howes
Keigan Kamey
Clayton Shilling

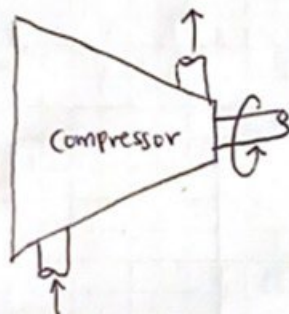
Problem Statement: An adiabatic air compressor compresses 10 L/s of air at 120 kPa and 20°C to 1000 kPa and 300°C. Determine (a) the work required by the compressor, in kJ/kg, and (b) the power required to drive the air compressor, in kW.

Known:

$$T_1 = 20^\circ\text{C} \quad P_1 = 120 \text{ kPa}$$

$$T_2 = 300^\circ\text{C} \quad P_2 = 1 \text{ MPa}$$

Find: Determine the work required by the compressor, in kJ/kg, and the power required to drive the air compressor, in kW.

Schematic:assumptions: no assumptionsProperties: All needed properties are knownAnalysis:

Solution plan -

$$a) W_{in} = C_p(T_2 - T_1)$$

$$T_{avg} = \frac{T_1 + T_2}{2} = \frac{20 + 300}{2} = 160^\circ\text{C} = 433 \text{ K}$$

$$\frac{C_p - 1.013}{(1.02 - 1.013)} = \frac{(433 - 2100)}{(450 - 2100)}$$

$$C_p = 1.01762 \text{ kJ/kg}$$

$$W_{in} = 1.01762(300 - 20)$$

$$= 284.933 \text{ kJ/kg}$$

$$b) \dot{m} = \rho_1 \dot{V}_1$$

$$\text{Density} = \rho_1 = \frac{P}{RT_1}$$

$$P_1 = (120 \times 10^3) \text{ Pa}$$

$$R = 0.287$$

$$T_1 = 293 \text{ K}$$

$$W = 1.427 \times 0.01 \times 284.933$$

$$= 4.0659 \text{ kW}$$

$$P_1 = 120 \times 10^3$$

$$(0.287 \times 10^3)(20 + 273)$$

$$= 1.427 \text{ kJ/m}^3$$

$$W_{in} = 284.933$$

$$V_1 = (10 \times 10^{-3}) \text{ m}^3/\text{s}$$

Comments: Use the right formula.

5-57

Temitayo Ojo
Christopher ScatesL.C. Hollis
Kerigan Kennedy
Clayton Strubling

Problem Statement % A portion of the steam passing through a steam turbine is sometimes removed for the purposes of feedwater heating as shown in Fig. P5-57. Consider an adiabatic steam turbine with 12.5 MPa and 550°C steam entering at a rate of 20 kg/s. Steam is bled from this turbine at 1000 kPa and 200°C with a mass flow rate of 1 kg/s. The remaining steam leaves the turbine at 100 kPa and 100°C. Determine the power produced by this turbine.

Knowns

$$P_1 = 12.5 \text{ MPa}$$

$$T_1 = 550^\circ\text{C}$$

$$T_2 = 200^\circ\text{C}$$

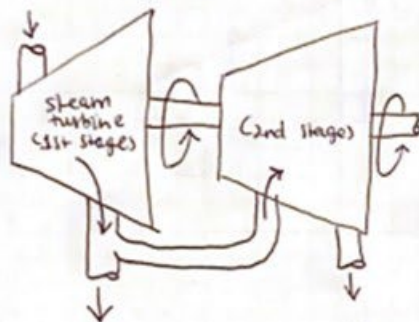
$$P_3 = 100 \text{ kPa}$$

$$m_1 = 20 \text{ kg/s}$$

$$P_2 = 1000 \text{ kPa}$$

$$m_2 = 1 \text{ kg/s}$$

$$T_3 = 100^\circ\text{C}$$

Find % Determine the power produced by this turbineSchematicassumptions % no assumptionsProperties % All needed properties are known.AnalysisSolution Plan

$$h_1 = 3476.5 \text{ kJ/kg}$$

$$h_2 = 2828.3 \text{ kJ/kg}$$

$$h_3 = 2675.8 \text{ kJ/kg}$$

$$W_1 = m_1 (h_1 - h_2)$$

$$= 20 (3476.5 - 2828.3)$$

$$W_1 = 12964 \text{ kW}$$

$$m_3 = m_1 - m_2 \quad m_3 = 19 \text{ kg/s}$$

$$= 20 - 1$$

$$W_2 = m_3 (h_2 - h_3)$$

$$= 19 (2828.3 - 2675.8)$$

$$W_2 = 2897.5 \text{ kW}$$

$$W = W_1 + W_2$$

$$= 12964 + 2897.5$$

$$W = 15860 \text{ kW}$$

Comment % Find all the missing parts to be able to find the power produced.

5-64

Temitayo Ojo
Christopher scalesL.C. Holmes
Keigan Kenney
Clayton Strickling

Problem Statement: An adiabatic capillary tube is used in some refrigeration systems to drop the pressure of the refrigerant from the condenser level to the evaporator level. The R-134a enters the capillary tube as a saturated liquid at 50°C and leaves at -20°C . Determine the quality of the refrigerant at the inlet of the evaporator.

Known:

$$T_1 = 50^\circ\text{C} \quad T_2 = -20^\circ\text{C}$$

Find: Determine the quality of the refrigerant at the inlet of the evaporator.

Schematic: no sketch

assumptions: no assumptions

Properties: all needed properties are known

Analysis:

Equation plan—

$$h_1 = h_2$$

$$h_2 = h_f + x(h_{fg})$$

Solution plan—

$$h_1 = h_f = 123.5 \text{ kJ/kg} = h_2$$

$$h_f = 25.49 \text{ kJ/kg}$$

$$h_{fg} = 212.91 \text{ kJ/kg}$$

$$h_2 = h_f + x(h_{fg})$$

$$123.5 = (25.49) + x(212.91)$$

$$x = 0.46$$

Comments: to find the quality you have to use the equation

$$x = \frac{h - h_f}{h_{fg}}$$

5-74

Temitayo Ojo

christopher scales

L.C. Howes

Keigan Kenney

clayton Strubling

Problem Statement: A hot-water stream at 80°C enters a mixing chamber with a mass flow rate of 0.5 kg/s where it is mixed with a stream of cold water at 20°C . If it is desired that the mixture leave the chamber at 42°C , determine the mass flow rate of the cold-water stream. Assume all the streams are at a pressure of 250 kPa .

Known:

$$T_1 = 80^\circ\text{C}$$

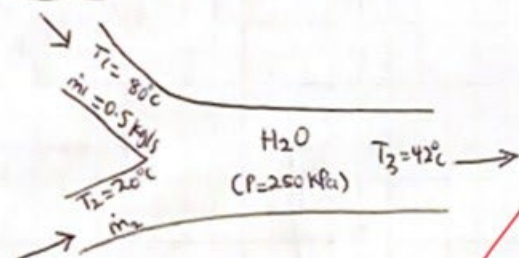
$$P = 250 \text{ kPa}$$

$$\dot{m}_1 = 0.5 \text{ kg/s}$$

$$T_3 = 42^\circ\text{C}$$

$$T_2 = 20^\circ\text{C}$$

Find: determine the mass flow rate of the cold-water stream.

Schematic:assumptions:

Assume all the streams are at a pressure of 250 kPa .

Properties: All needed properties are known

Analysis:

Equation plan -

$$\dot{m}_{in} = \dot{m}_{out}$$

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{m}_1 h_1 = \dot{m}_2 h_2 + \dot{m}_3 h_3$$

$$\dot{m}_1 (h_3 - h_1) = \dot{m}_2 (h_2 - h_3)$$

$$\dot{m}_2 = \frac{h_3 - h_1}{h_2 - h_3} \dot{m}_1$$

Solution plan -

$$h_1 = h_f = 335.02 \text{ kJ/kg}$$

$$h_2 = h_f = 83.915 \text{ kJ/kg}$$

$$h_3 = h_f = 167.53 + (188.44 - 167.53) \left(\frac{42 - 40}{45 - 40} \right)$$

$$h_f = h_3 = 175.894 \text{ kJ/kg}$$

$$\dot{m}_2 = \frac{175.894 - 335.02}{83.915 - 175.894} \times 0.5$$

$$\dot{m}_2 = 0.865$$

Comment: Find the enthalpies and plug it in the right mass flow rate equation.

5-81

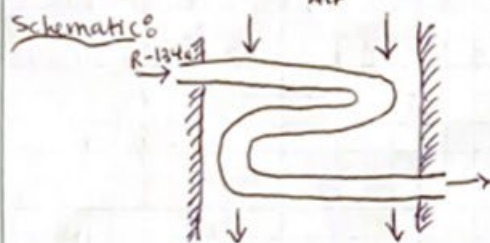
Temitayo Oso
Christopher ScatesL.C. Hollis
Keigan Kenney
Clayton Strubling

Problem Statement: Refrigerant-134a at 1 MPa and 90°C is to be cooled to 1 MPa and 30°C in a condenser by air. The air enters at 100 kPa and 27°C with a volume flow rate of 600 m³/min and leaves at 95 kPa and 60°C. Determine the mass flow rate of the refrigerant.

Known:

$$\begin{aligned} P_1 &= 1 \text{ MPa} & \dot{V}_3 &= 600 \text{ m}^3/\text{min} & P_4 &= 95 \text{ kPa} \\ T_1 &= 90^\circ\text{C} & P_3 &= 100 \text{ kPa} & T_4 &= 60^\circ\text{C} \\ & & T_3 &= 27^\circ\text{C} & & \\ P_2 &= 1 \text{ MPa} & & & & \\ T_2 &= 30^\circ\text{C} & & & & \end{aligned}$$

Find: Determine the mass flow rate of the refrigerant.

Schematic:

assumptions: no assumptions

Properties: All needed properties are known

Analysis:Equation plan-

$$\dot{V}_1 = \frac{\dot{m} R T_1}{P_1}$$

$$\dot{m}_R = \frac{h_3 - h_1}{h_3 - h_4} \dot{m}_a$$

Solution plan-

$$h_3 = 324.66 \text{ kJ/kg}$$

$$h_4 = 93.58 \text{ kJ/kg}$$

$$\dot{V}_1 = \frac{(100 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K})(300 \text{ K})}{100 \text{ kPa}} = 0.861 \text{ m}^3/\text{kg}$$

$$\dot{m}_a = \frac{\dot{V}_1}{v_1} = \frac{600 \text{ m}^3/\text{min}}{0.861 \text{ m}^3/\text{kg}} = 696.9 \text{ kg/min}$$

$$\dot{m}_R = \frac{h_3 - h_1}{h_3 - h_4} \dot{m}_a = \frac{(P(T_3 - T_1))}{h_3 - h_4} \dot{m}_a = \frac{100 \text{ kJ} \cdot \text{C} (60 - 27^\circ\text{C})}{324.66 \text{ kJ/kg} - 93.58 \text{ kJ/kg}} (696.9 \text{ kg/min})$$

$$= \frac{33.165 \text{ kJ/kg}}{231.08 \text{ kJ/kg}} (696.9 \text{ kg/min}) = 100 \text{ kg/min}$$

comment: Use the right equation/formula

5-116

Temitayo Ojo

Christopher Scales

L.C. Hollies

Keigan Kenney

Clayton Striking

Problem Statement: A 2-m³ rigid tank initially contains air at 100 kPa and 22°C. The tank is connected to a supply line through a valve. Air is flowing in the supply line at 600 kPa and 22°C. The valve is opened, and air is allowed to enter the tank until the pressure in the tank reaches the line pressure, at which point the valve is closed. A thermometer placed in the tank indicates that the air temperature at the final state is 77°C. Determine (a) the mass of air that has entered the tank and (b) the amount of heat transfer.

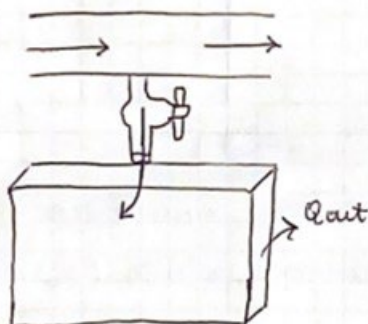
Known:

$$P_i = 600 \text{ kPa} \quad V = 2 \text{ m}^3$$

$$T_i = 22^\circ\text{C} \quad P_1 = 100 \text{ kPa}$$

$$T_1 = 22^\circ\text{C}$$

Find: Determine the mass of air that has entered the tank and the amount of heat transfer.

Schematic:Assumptions: no assumptionsProperties: All needed properties are knownAnalysis:

$$m_i + m_e = m_2 - m_1$$

$$11.95 - 2.36 = 9.58 \text{ kg}$$

$$Q - W = m_e h_e - m_i h_i + m_2 u_2 - m_1 u_1$$

$$Q = (9.58)(295.17) + (11.95)(250.02) - (2.36)(210.45)$$

$$Q = 339$$

$$\frac{P_1 V}{RT} = \frac{100(2)}{0.287(295)} = 2.36$$

$$\frac{P_2 V}{RT} = \frac{600(2)}{350(295)} = 11.95$$

Comments: First law expanded equation is needed

5-183

Christopher scales

Morgan Kenner
Clayton Stabbing

Problem Statement: A piston-cylinder device initially contains 1.2 kg of air at 700 kPa and 200°C. At this state, the piston is touching on a pair of stops. The mass of piston is such that 600-kPa pressure is required to move it. A valve at the bottom of the tank is opened, and air is withdrawn from cylinder. The valve is closed when the volume of the cylinder decreases to 80 percent of the initial volume. If it is estimated that 40 kJ of heat is lost from the cylinder,

Known:

$$m = 1.2 \text{ kg}$$

$$P = 700 \text{ kPa}$$

$$T = 200^\circ\text{C}$$

Find: determine the final temperature of the air in the cylinder, the amount of mass that has escaped from the cylinder, and the work done.

Schematic:



Assumptions: If it is estimated that 40 kJ of heat is lost from the cylinder

Properties: All needed properties are known

B10

Analysis:

Equation Plan -

$$T_c = \frac{(T_1 + T_2)}{2}$$

$$m_{in} - m_{out} = \Delta m_{system}$$

$$m_c = m_1 - m_2$$

$$m_2 = \frac{P_2 V_2}{RT}$$

$\neq 0$

$$V_1 = \frac{mRT}{P_1}$$

$$W_{b, in} = P_2 (V_1 - V_2)$$

Solution Plan -

$$C_p = 0.753 \text{ kJ/kg}$$

$$C_v = 1.020 \text{ kJ/kg}$$

$$T_1 = 200 \rightarrow 473$$

$$V_2 = 0.80 V_1$$

$$V_2 = 0.80 (0.2327)$$

$$= 0.1862 \text{ m}^3$$

$$m_2 = \frac{P_2 V_2}{RT}$$

$$= \frac{600(0.1862)}{(0.287)(T_2)}$$

$$= 389.18$$

$$= \frac{2(0.287)(473)}{700}$$

$$= 0.2327 \text{ m}^3$$

$$= (12 - \frac{389.18}{T_2})$$

Not clearly presented

$$27.9 - 40 - \left[12 - \frac{389.18}{T_2} \right] 1.020 \left(\frac{473 + T_2}{2} \right)$$

$$= \left[\frac{389.18}{T_2} \right] (0.753) T_1 - (0.2) (0.753) (473)$$

$$\frac{1}{T_2} = 4.15 \text{ K} \quad m = 12 - \frac{389.18}{4.15} = 0.2622$$

How was this solved?

Comments: Be careful with the formulas.

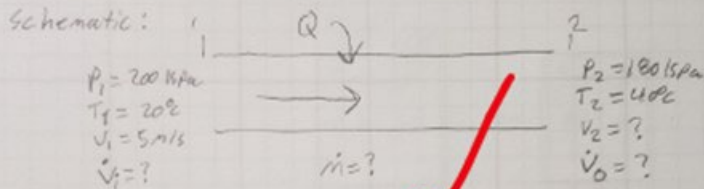
BELOW AVERAGE

Problem 5-6

Statement: Air enters a 16-cm-diameter pipe steadily at 200 kPa and 20°C with a velocity of 5 m/s. Air is heated as it flows, and it leaves the pipe at 180 kPa and 40°C. Determine (a) the volume flow rate of air at the inlet, (b) the mass flow rate of air, and (c) the velocity and volume flow rate at the exit.

Know: Pressure 1, 200 kPa; Velocity 1, 5 m/s; Temp. 1, 20°C
Pressure 2, 180 kPa; Temp. 2, 40°C

Find: Volume flow rate, mass flow rate, Velocity 2.



Assumption: None.

Properties: All are known.

10/10

Analysis:

$$(A) \quad P_1 V_1 = n R T_1 \\ P_1 = \frac{n R T_1}{V_1} \\ P_1 = \frac{\rho_1 R T_1}{M}$$

$$\rho_1 = \frac{P_1}{0.287 \cdot (20 + 273)} = 2.378$$

$$\dot{V}_1 = A V_1 = \frac{\pi}{4} \cdot (0.16)^2 \cdot 5 \\ \dot{V}_1 = 0.10048 \text{ m}^3/\text{s}$$

$$(B) \quad \dot{m} = \rho_1 A V_1 \\ = 2.378 \cdot 0.10048 \\ \dot{m} = 0.2388 \text{ kg/s}$$

$$(C) \quad P_2 V_2 = n R T_2 \\ P_2 = \frac{n R T_2}{V_2} = \frac{180}{0.287 \cdot (40 + 273)} = 2.0027$$

$$\dot{m} = \rho_2 A V_2 \\ V_2 = \frac{\rho_1 A}{\rho_2} = \frac{(2.378) \cdot \frac{\pi}{4} \cdot (0.16)^2}{2.0027} \\ V_2 = 5.933 \text{ m/s}$$

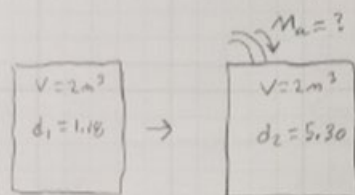
$$\dot{V}_2 = A V_2 = \frac{\pi}{4} (0.16)^2 \cdot 5.933 \\ \dot{V}_2 = 0.11922 \text{ m}^3/\text{s}$$

Statement: A 2 m^3 rigid tank initially contains air whose density is 1.18 kg/m^3 . The tank is connected to a high-pressure supply line through a Valve. The valve is opened, and air is allowed to enter the tank until the density in the tank rises to 5.30 kg/m^3 . Determine the mass of air that has entered the tank.

Known: Volume, 2 m^3 ; Density₁, 1.18 kg/m^3 ; Density₂, 5.30

Find: mass of air entering the tank.

Schematic:



Assumption: initial Volume equals final volume

Properties: $\text{mass} = \text{Density} \cdot \text{Volume}$

9/10

Analysis:

$$V = 2\text{ m}^3$$

$$m_1 = 1.18 \cdot 2 = 2.36\text{ kg}$$

$$m_2 = 5.30 \cdot 2 = 10.6\text{ kg}$$

Show equations being used.

$$\Delta m = m_2 - m_1$$

$$\Delta m = 10.6 - 2.36$$

$$\Delta m = 8.24\text{ kg}$$

Comments: Δm is mass of air entering the tank.

Problem 5-33

$$P_1 = 800 \text{ kPa}$$

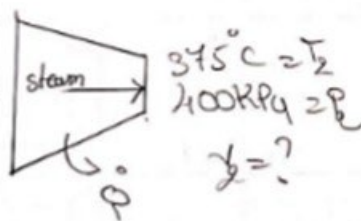
$$\nu_1 = 0.38429 \text{ m}^3/\text{kg}$$

$$h_1 = 3267.7 \text{ kJ/kg}$$

$$T_1 = 400^\circ\text{C}$$

$$P_2 = 800 \text{ kPa}$$

$$\dot{V}_1 = 10 \text{ mL/s}$$



$$P_2 = 400 \text{ kPa}$$

$$T_2 = 375^\circ\text{C}$$

$$\rho_2 = 0.74321$$

$$h_2 = 3222.2$$

velocity of the steam

$$\dot{Q} - \dot{W} = \dot{m} \left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} + \Delta P_e \right]$$

$$\Rightarrow -\dot{Q} - 0 = \left(\frac{P V_1}{\nu_1} \right) \left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} + 0 \right]$$

$$\Rightarrow -25 \times 10^3 = \left(\frac{800 \times 10^{-4} \times 10}{0.38429} \right) \left[(3222.2 - 3267.7) \times 10^3 + \frac{V_2^2 - 10}{2} \right]$$

$$\Rightarrow \boxed{V_2 = 260 \text{ m/s}}$$

The volume flow rate

$$\dot{V}_2 = \dot{m} \nu_2 = \left(\frac{P V_1}{\nu_1} \right) \times \nu_2 = \frac{800 \times 10^{-4} \times 10}{0.38429} \times 0.74321$$

$$\Rightarrow \boxed{\dot{V}_2 = 1.55 \text{ m}^3/\text{s}}$$

10/10

Problem 5-48

10/10

$$\begin{aligned} P_1 &= 4 \text{ MPa} \\ T_1 &= 500^\circ\text{C} \\ V_1 &= 80 \text{ m/s} \end{aligned} \left\{ \begin{aligned} \dot{V}_1 &= 0.0864 \text{ m}^3/\text{s} \\ \dot{h}_1 &= 29,446 \text{ kJ/kg} \end{aligned} \right.$$

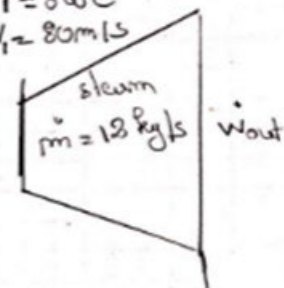
$$\begin{aligned} P_2 &= 30 \text{ kPa} \\ T_2 &= ? \\ x_2 &= 0.92 \\ V_2 &= 50 \text{ m/s} \end{aligned} \left\{ \begin{aligned} h_f &= 289.27 \text{ kJ/kg} \\ h_{fg} &= 2,335.3 \text{ kJ/kg} \end{aligned} \right.$$

$$h_2 = h_f + x_2 h_{fg}$$

$$h_2 = 289.27 \text{ kJ} + (0.92)(2,335.3 \text{ kJ/kg})$$

$$h_2 = 2,437.7 \text{ kJ/kg}$$

$$\begin{aligned} P_1 &= 4 \text{ MPa} \\ T_1 &= 500^\circ\text{C} \\ V_1 &= 80 \text{ m/s} \end{aligned}$$



$$\begin{aligned} P_2 &= 30 \text{ kPa} \\ x_2 &= 0.92 \\ V_2 &= 50 \text{ m/s} \end{aligned}$$

a) Determine the change in kinetic Energy

$$\begin{aligned} \Delta K_e &= \frac{V_2^2 - V_1^2}{2} \\ &= \frac{50^2 - 80^2}{2} \\ &= -1.950 \text{ m}^3/\text{s}^2 \times \left(\frac{1 \text{ kJ/kg}}{1000 \text{ m}^2/\text{s}^2} \right) \end{aligned}$$

$$\Rightarrow \Delta K_e = -1.95 \text{ kJ/kg}$$

b) The power out

$$m_2 = m_1$$

$$E_{in} - E_{out} = \frac{dE}{dt}$$

$$\Rightarrow E_{in} - E_{out} = 0 \text{ (Steady)}$$

(2)

 $E_{in} = E_{out}$

$$m(h_1 + V_1^2/2) = W_{out} + m(h_2 + V_2^2/2)$$

$$W_{out} = m(h_2 - h_1 + \frac{V_2^2 - V_1^2}{2})$$

$$W_{out} = 12 \text{ kg/s} \left(2737.7 - 3446 + \frac{50^2 - 80^2}{2} \right) \left(\frac{1 \text{ kg} \cdot \text{J}}{1000 \text{ kg}} \right)$$

$$= 12,123 \text{ kW} \left(\frac{1 \text{ MW}}{1000 \text{ kW}} \right)$$

$$\text{so } W_{out} = 12.1 \text{ MW}$$

c) Calculate the inlet area

$$A_1 = \frac{m \bar{v}_1}{V_1}$$

$$A_1 = \frac{12 \text{ kg/s} \times (0.086442 \text{ m}^3/\text{kg})}{80 \text{ m/s}}$$

$$A_1 = 0.0130 \text{ m}^2$$

5-57

Statement A portion of the steam passing through a steam turbine is sometimes removed for the purposes of feedwater heating as shown in Fig. P5-57. Consider an adiabatic steam turbine with 12.5 MPa and 550°C steam entering at a rate of 20 kg/s. Steam is bled from this turbine at 100 kPa and 200°C with a mass flow rate of 1 kg/s. The remaining steam leaves the turbine at 100 kPa and 100°C. Determine the power.

Known $P_1 = 12.5 \text{ MPa}$, $T_1 = 550^\circ\text{C}$, $\dot{m}_1 = 20 \text{ kg/s}$, $P_2 = 100 \text{ kPa}$, $T_2 = 200^\circ\text{C}$, $\dot{m}_2 = 1 \text{ kg/s}$, $P_3 = 100 \text{ kPa}$, $T_3 = 100^\circ\text{C}$

Show system

Find Power produced by turbine

Assumption $\dot{Q} = 0$ (adiabatic)

Analysis

$$\dot{W}_1 = 20(3476.5 - 2828.3)$$

$$20(648.2) = 12,964 \text{ W}$$

$$\dot{W}_2 = 19(2828.3 - 2675.8)$$

$$19(152.5) = 2897.5 \text{ W}$$

9/10

$$\dot{W} = \dot{W}_1 + \dot{W}_2$$

$$\dot{W} = 12,964 + 2,897.5$$

$$\dot{W} = 15,861.5 \text{ W}$$

5-69

Statement An adiabatic capillary tube is used in some refrigeration systems to drop the pressure of the refrigerant from the condenser level to the evaporator level. The R-134a enters the capillary tube as a saturated liquid at 50°C and leaves at -20°C . Determine the quality of the refrigerant at the inlet of the evaporator.

Known $T_1 = 50^\circ\text{C}$, $T_2 = -20^\circ\text{C}$, $h_{f50} = 123.49$, $h_{f-20} = 25.49$, $h_{fg-20} = 212.91$

Find Quality of the refrigerant at the inlet

Assumption Isenthalpic, $x_2 = \frac{h_2 - h_f}{h_{fg}}$

Analysis $h_1 = h_f = h_2$

$$x = \frac{123.49 - 25.49}{212.91} = 0.46$$

10/10

5-74

Statement A hot water stream at 80°C enters a mixing chamber with a mass flow rate of 0.5 kg/s where it is mixed with a stream of cold water at 20°C . If it is desired that the mixture leave the chamber at 42°C , determine the mass flow rate of the cold water stream. Assume all the streams are at a pressure of 250 kPa .

Known $T_1 = 80^\circ\text{C}$, $T_2 = 20^\circ\text{C}$, $T_3 = 42^\circ\text{C}$, $\dot{m}_1 = 0.5 \text{ kg/s}$

Find mass flow rate of the cold water stream

7/10

Assumption All streams have a pressure of 250 kPa
Need to set up the problem

At 80°C $h_{\text{hot}} = 335.1$

At 20°C $h_{\text{cold}} = 81.1$

At 42°C $h_{\text{mix}} = 176.1$

$$\dot{m}_{\text{cold}} = \frac{(0.5)h_{\text{hot}} - (0.5)h_{\text{mix}}}{(h_{\text{cold}} - h_{\text{mix}})}$$

Analysis

$$\dot{m}_{\text{cold}} = \frac{(0.5)(335.1) - (0.5)(176.1)}{81.1 - 176.1} = 0.864 \text{ kg/s} ??$$

5-187

given

$$P_3 = 12.5 \text{ MPa}$$

$$h_3 = 3341.8 \text{ kJ/kg}$$

$$T_3 = 500^\circ\text{C}$$

$$K_{gt} =$$

$$P_4 = 10 \text{ kPa}$$

0/10

$$x_6 = 0.92$$

assumption

$$h_4 = h_f + x h_{fg}$$

Wrong problem

$$h_4 = 191.83 + 0.92 \times 2393.2 = 2393.2 \text{ kJ/kg}$$

$$T_1 = 295 \text{ K}$$

$$h_1 = 295.17$$

$$T_2 = 620 \text{ K}$$

$$h_2 = 628.07$$

Analysis

$$W = m_{\text{net}} (h_2 - h_1)$$

$$= 10 \cdot (628.07 - 295.17) = 3329 \text{ kW}$$

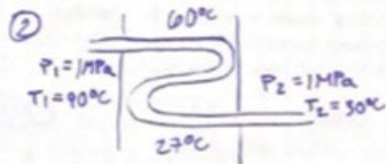
$$W = 25 \cdot (3341.8 - 2393.2) = 23715 \text{ kW}$$

$$W = 23715 - 3329$$

$$W_{\text{net}} = 20386 \text{ kW}$$

5-81

- ① Refrigerant-134a at 1 MPa and 90°C, is cooled to 1 MPa and 30°C. Air enters at 100 kPa and 27°C with $\dot{V} = 600 \text{ m}^3/\text{min}$. Determine the mass flow rate.



- ③ $\dot{m}$ in kg/min $\dot{m} \approx 80 \text{ kg/min} - 100 \text{ kg/min}$

④ $\dot{m} = \frac{\dot{V}}{v}$ $V = \dot{m} \times v$ $Pv = RT$

⑤ $P_1 = 1 \text{ MPa}$ $T_1 = 90^\circ\text{C}$ $\dot{V} = 600 \text{ m}^3/\text{min}$
 $P_2 = 1 \text{ MPa}$ $T_2 = 30^\circ\text{C}$ $h_1 = 324.66$
 air $c_p = 1.005 \text{ kJ/kg}$ $h_2 = 93.58$

⑥ $\dot{m}$ of air

$$\frac{(600 \text{ m}^3/\text{min})(100 \text{ kPa})}{27^\circ\text{C} \times (8.314)} = 696.515 \text{ kg/min}$$

$$\dot{m} = \frac{696.515 \times 1.005 (60 - 27)}{(324.66 - 93.58)} = 100 \text{ kg/min} \text{ rounded}$$

- ⑦ The mass flow rate of refrigerant-134a is 100 kg/min from the process that occurs in the system.

5-116

- ① A 2-m³ rigid tank contains air at 100 kPa and 22°C. Tank has a valve with a supply line flowing at 600 kPa and 22°C. The valve is opened then closed and has 77°C at the final state.
 a) Determine the mass of the air
 b) amount of heat transfer

10/10

②



③

Volume constant: $V = 2 \text{ m}^3$
 mass will be around 10 kg

④

$$22^\circ\text{C} \rightarrow 295 \text{ K} \quad 77^\circ\text{C} \rightarrow 350 \text{ K}$$

$$h_1 = 295.17 \text{ kJ/kg} \quad h_2 = h_1 \quad R = 0.287$$

$$u_1 = 210.49 \text{ kJ/kg}$$

$$u_2 = 250.02 \text{ kJ/kg}$$

⑤

Need mass · heat transfer

⑥

$$m_2 - m_1 = \frac{P_2 V}{R T_2} - \frac{P_1 V}{R T_1} = \frac{600 \times 2}{0.287 \times 350} - \frac{100 \times 2}{0.287 \times 295} = 9.58 \text{ kg}$$

$$b) Q = -(m_2 - m_1)h_1 + m_2 u_2 - m_1 u_1$$

$$= -(11.94 - 2.36)295.17 + (11.94 \times 250.02) - (2.36 \times 210.49)$$

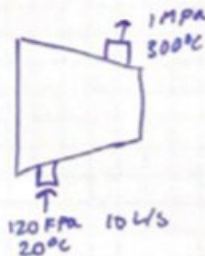
$$Q = 339 \text{ kJ}$$

⑦ The mass of air is 9.58 kg and the heat transfer is 339 kJ.

5-52

- ① Adiabatic air compressor compresses 10 L/s of air at 120 kPa and 20°C to 1000 kPa and 300°C
- Determine the work required
 - Power required to drive the air compressor

②



$$C_{pa} = 1.005 \text{ kJ/kg} \cdot \text{K}$$

9/10

③

- closed system - work $\approx 280 \text{ kJ/kg}$
- power $\approx 4 \text{ kW}$

④

$$\text{Work} = h_2 - h_1 = C_{pa}(T_2 - T_1) \quad T_1 = 293 \text{ K} \quad h_1 =$$

$$\text{Power} = \dot{m}(h_2 - h_1) \quad T_2 = 573 \text{ K} \quad h_2 =$$

$$\text{Work} = 1.005(573 - 293) = 281.4 \text{ kJ/kg}$$

$$\text{Power} = (281.4) \times (0.01427) = 4.016 \text{ kW}$$

$$? = \frac{P_1}{R T_1} = \frac{120 \times 10^3}{287 \times 293} = 1.427 \text{ kg/m}^3 \times 10^{-2} = 0.01427 \text{ kg/s}$$

Needs to be computed before computing Power

**THERMODYNAMICS I
FALL 2021**

HOMEWORK 6

TOPICS COVERED IN HOMEWORK 6

Homework 6 covered the topics:

1. Ideal and non ideal vapor compression refrigeration and heat pump cycles
2. Cascade, multistage and multipurpose refrigeration systems
3. Gas refrigeration cycles

THERMODYNAMICS I
FALL 2021

HOMEWORK #6 QUESTIONS

**Formal: Problems 6.16, 6.23, 6.25, 6.43, 6.53 ,
6.57, 6.84E, 6.107, 6.111, 6.142,**

ABOVE AVERAGE

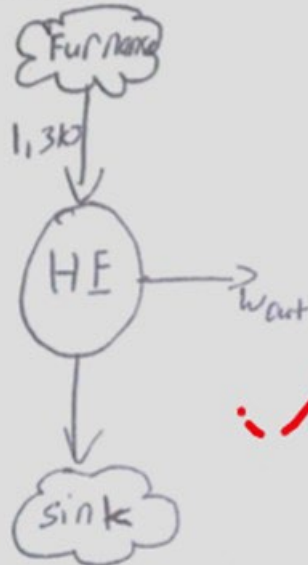
G16

Known:

heat input - 1,3 kJ

thermal efficiency - 35%

Schematic:



10/10

Find: How much work will it produce?

Assumptions: Since it is not isochoric or isobaric the work done will be more than zero.

Equations:

$$W_{net} = \eta_{th} Q_H$$

$$W_{net} = (0.35)(1.3)$$

$$= 0.455 \text{ kJ}$$

6.23

known:

fuel consumed - 22 L/h

delivers - 55 kW power

heating value - 44,000 kJ/kg

density - 0.8 g/cm³

10/10

Schematic, none

Find! Determine the efficiency of this engine equations!

Volume of fuel consumed

$$= \frac{22}{60 \times 60} \text{ L/s} = 6.11 \times 10^{-3} \text{ L/s}$$

$$V = 1000 \times 6.11 \times 10^{-3} \\ = 6.11 \text{ cm}^3$$

$$M = V\rho = 6.11 \times 0.8 \text{ g} = 4.888 \text{ g} = 4.888 \times 10^{-3} \text{ kg}$$

$$Q = HM = 44000 \times 4.888 \times 10^{-3} = 215.07 \text{ kJ}$$

$$\text{efficiency} = \frac{55}{215.07} \frac{\text{Power}}{Q} = 0.256$$

$$\eta = 25.6\%$$

25.6

November 28th, 2021 | Homework #6, 6-25 | Jerremy Haines

Given: Net power produced by plant

$$W_{\text{net}} = 300 \text{ MW} \quad \text{Thermal efficiency, } \eta_{\text{th}} = 32\%$$

$$\text{Air-fuel ratio, } A/F = 12 \text{ kg/kg fuel} \quad HV = 28,000 \text{ kJ/kg}$$

$$\begin{aligned} \text{a) } \eta_{\text{th}} &= \frac{W_{\text{net}}}{Q_{\text{in}}} \quad \text{+ } Q_{\text{in}} = \text{heat input} \\ &\Rightarrow Q_{\text{in}} = \frac{300}{0.32} \text{ MW} \\ &\Rightarrow Q_{\text{in}} = 937.5 \times 10^3 \text{ kW} \end{aligned}$$

* Rate of heat supplied to power plant

10/10

$$Q_{\text{in}} = \dot{m}_f \times HV$$

$$\begin{aligned} \dot{m}_{\text{coal}} &= \frac{Q_{\text{in}}}{HV} \\ &= \frac{937.5 \times 10^3}{28,000} \\ &= 33.48 \text{ kg/s} \end{aligned}$$

$$\begin{aligned} \dot{m}_{\text{coal}} &= 33.48 \times 24 \times 3600 \\ &= 2.89 \times 10^6 \text{ kg} \end{aligned}$$

$$\text{Amount of coal consumed} = 2.89 \times 10^6 \text{ kg}$$

b) Air flow through furnace

$$A/F = \frac{\dot{m}_{\text{air}}}{\dot{m}_{\text{coal}}}$$

$$\begin{aligned} \dot{m}_{\text{air}} &= 12 \times 33.48 \\ &= 401.76 \text{ kg/s} \end{aligned}$$

mass of air flow

$$402 \text{ kg/s}$$

November 29th, 2021

Homework #6, 6-43

Jerremy Barnes

Given: 15,000 kJ/h cooling effect

Rejects: 22,000 kJ/h of heat

Calculate COP

Coefficient of Performance

$$\text{COP} = \frac{\text{Desired Result}}{\text{Required Input}}$$

$$\text{COP}_R = \frac{Q_L}{W_{\text{net in}}}$$

First law of cyclic refrigeration

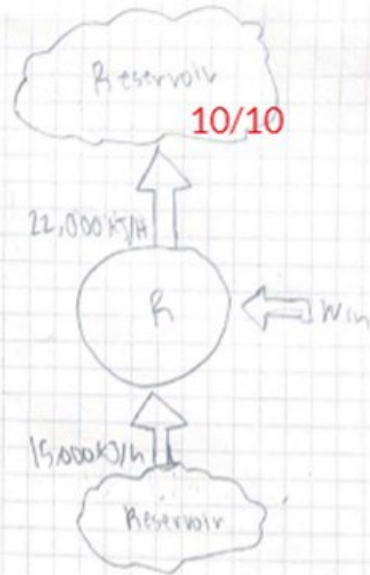
$$\text{COP}_R = \frac{Q_L}{Q_H - Q_L}$$

Given: $Q_L = 15,000 \text{ kJ/h}$

$Q_H = 22,000 \text{ kJ/h}$

$$\begin{aligned}\text{COP}_R &= \frac{15,000 \text{ kJ/h}}{22,000 - 15,000} \\ &= \frac{15,000 \text{ kJ/h}}{7,000 \text{ kJ/h}}\end{aligned}$$

$$\boxed{\text{COP}_R = 2.14}$$

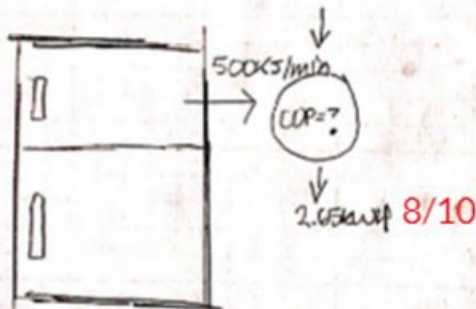


6-53

Given: $T_i = 23^\circ\text{C}$, $T_c = 5^\circ\text{C}$ $\dot{Q}_{\text{ref}} = 570 \text{ kJ/min}$, $P = 2.65 \text{ kW}$ $C = 4.18 \text{ kJ/kg}\cdot^\circ\text{C}$, $d = 1 \text{ kg/L}$

Find: RATE AT WHICH WATER IS COOLED & COP

FBD



ANALYSIS: $\dot{Q}_H = 570 \frac{\text{kJ}}{\text{min}} \times \frac{1000 \text{ J}}{1 \text{ kJ}} \times \frac{1 \text{ min}}{60 \text{ sec}} = 9500 \text{ W}$

$\text{COP} = \frac{Q_c}{W} = \frac{Q_H - W}{W} \Rightarrow \frac{9500 \text{ W} - 2650 \text{ W}}{2650 \text{ W}} = 2.585 \text{ W}$

$Q_c = (\text{COP})(W) \Rightarrow 2.585 \text{ W} \times 2650 \text{ W} = 6850.25 \text{ W}$ Work not logically sequenced

$\frac{Q}{t} = \frac{mC\Delta T}{t} \Rightarrow \frac{6850.25 \text{ W}}{1 \text{ W}} = \left(\frac{V}{t}\right) \rho C\Delta T$

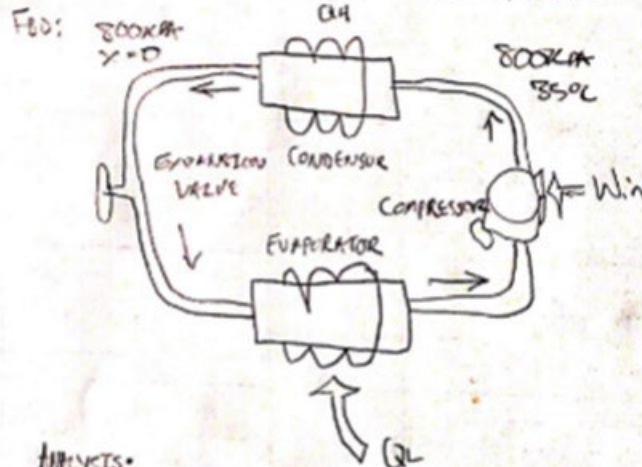
$11 = \frac{V}{t} = \frac{6850.25 \text{ W}}{(1000 \text{ kg/m}^3)(4186 \text{ J/kg}\cdot^\circ\text{C})(23^\circ\text{C} - 5^\circ\text{C})}$
 $= \boxed{5.4548 \rightarrow 5.46 \text{ L/min}}$

6-57

Given: $P_1 = 800 \text{ kPa}$, $T_1 = 35^\circ\text{C}$
 $m = 0.018 \text{ kg/s}$, $P_2 = 800 \text{ kPa}$, $X_2 = 0$
 Work 1.2 kW

10/10

Find: COP of heat pump, rate of heat absorption



Analysis:

enthalpy @ $P_1 = 800 \text{ kPa}$, $T = 35^\circ\text{C}$

$$h_f = 267.29 + (276.45 - 267.29) \left(\frac{35 - 31.31}{40 - 31.31} \right) = 271.2 \text{ kJ/kg}$$

enthalpy @ $P_2 = 800 \text{ kPa}$ and $X_2 = 0$

$$h_g = 93.58 + (96.42 - 93.58) \left(\frac{800 - 770.64}{845.89 - 770.64} \right) = 95.46 \text{ kJ/kg}$$

$$\text{COP, } Q_H = m(h_g - h_f) \Rightarrow 0.018(271.17 - 95.46) = 3.16 \text{ kW}$$

6-57 (cont'd)

$$\text{COP}_H = \frac{Q_H}{W_{\text{out}}} = \frac{15.16 \text{ kW}}{1.2 \text{ kW}} = \boxed{2.633 \text{ kW}}$$

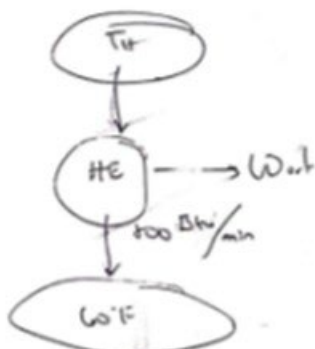
Rate of Heat Absorption

$$Q_L = Q_H - W_{\text{out}} \\ = 15.16 \text{ kW} - 1.2 = \boxed{1.96 \text{ kW}}$$

6.842 Given: ~~11/11/21~~ $T_c = 60^\circ\text{F}$, $Q_c = 800$, $\eta = 75\%$

Find: Determine the power output of the engine and b) the temperature of the source.

Schematic:



9/10

Assumptions: We will need to find the heat in order to find the work.

Properties: Power output can be found using the following equation: $Q_H = Q_c / \eta$

Use parenthesis where needed
Work not clearly presented

Analysis: $\eta = Q_H - Q_c / Q_H = W / Q_H = 1 - Q_c / Q_H = 0.75$

a) - $\eta = 0.75$

$$W = (\eta)(Q_H) = (0.75)(3200) \left(\frac{1}{0.0235} \right)$$

$$(2400)(0.0235) = \eta \cdot W \cdot \text{hp}$$

56.6

2080

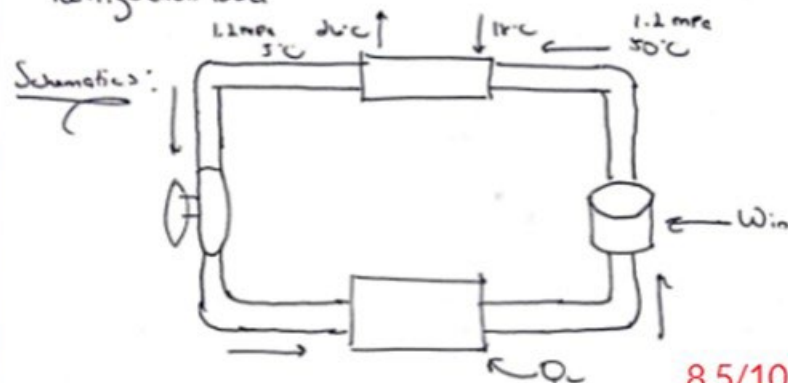
b) - $\eta = 1 - T_c / T_H = 1 - 60 + 460 / T_H = 0.75$

$$T_H = \frac{500}{0.75} = 666.67^\circ\text{F}$$

6-107

Known: $T_1 = -35^\circ\text{C}$, $T_2 = 18^\circ\text{C}$, $T_3 = 26^\circ\text{C}$, $T_4 = 80^\circ\text{C}$,
 $T_5 = 5^\circ\text{C}$, $v_1 = 0.35$, $P = 1.2\text{ MPa}$, $\dot{W}_{\text{in}} = 7.3\text{ kW}$

Find: Determine a) the mass flow rate of refrigerant, b) the refrigerant load, c) the COP, and d) the minimum possible input to the compressor for the same refrigeration load



8.5/10

Assumptions: The saturated water tables will be needed to complete the problem.

Properties: The enthalpy will need to be found at two points using the 12th - refrigerant table

Analysis: $T_3 = T_2 (1.2\text{ MPa}) + T_{\text{sub}}$

$$T_3 = 46.3 \text{ at } 1.2\text{ MPa} - 5^\circ\text{C} = 41.3^\circ\text{C}$$

$$\dot{W}_1 = \dot{h}_{1f,c} + \dot{h}_{2w} - \dot{h}_{1f,c} \quad \text{at } 20 - 25^\circ\text{C} \quad (20-25)$$

$$= (825.15 - 62.972) / 8 \quad (2)$$

$$\dot{W}_2 = \dot{h}_{3f,c} - \dot{h}_{2w} - \dot{h}_{3f,c} \quad \text{at } 70 - 85^\circ\text{C} \quad (70-85)$$

$$= 104.83 + (125.75 - 104.83) / 8 \quad (4)$$

$$= 107.01 \text{ kJ/kg}$$

6-101
a) $Q_H = m(h_2 - h_1) = 0.35(105.01 - 75.54) = 10.367 \text{ kW}$

$m = Q_H / (h_1 - h_2) = 10.367 / (274.22 - 110.15) = 0.0498 \text{ kg/s}$

h_1 at 1.3 MPa = 274.22
 $h_2 = 110.15$

b) $Q_C = Q_H - W = 10.367 - 5.30 = 5.07 \text{ kW}$

$W = 5.30 \text{ kW}$
 $Q = 10.367$

c) $\text{COP}_R = Q / W_{in} = 5.07 / 3.3 = 1.54$

d) $\text{COP}_{max} = 1 / (T_H / T_C - 1) = 1 / (291 / 231) - 1 = 4.49$

$T_C = -35^\circ\text{C} = 238 \text{ K}$
 $T_H = 15^\circ\text{C} = 288 \text{ K}$

$T_H = 15^\circ\text{C} \rightarrow 15 + 273 = 288$

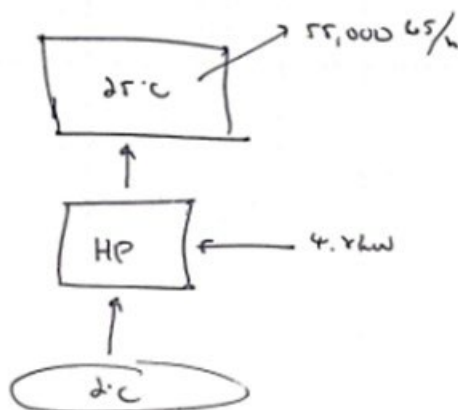
$W = Q_C / \text{COP}_{max} = 5.07 / 4.49 = 1.13 \text{ kW}$

6.11

known: $T_H = 25^\circ\text{C}$, $T_L = 2^\circ\text{C}$, $Q_H = 55,000 \text{ kJ/h}$
 $W = 4.8 \text{ kW}$

Find: How long the heat pump run on that day, b) the total heating costs, assuming an average price of \$0.11 per electricity, and c) the heating cost for the same day if resistance heating is used.

Schematics:



Assumptions: Temperatures will have to be converted to Kelvin and the heat will be used to find the work

Properties: Q_H is already known and can be used throughout the problem

8.5/10

Analysis: Difficult to read work

$$g) - COP_{HP} = \frac{1}{1 - (T_L/T_H)} = \frac{1}{1 - (273/298)} = 12.96$$

$$2^\circ\text{C} \rightarrow 273\text{K}$$

$$25^\circ\text{C} \rightarrow 298\text{K}$$

$$24\text{hr} \rightarrow 1\text{ day}$$

$$W_{\text{heat}} = Q_H / COP = 55,000 (24) / 12.96$$

$$= 101,820$$

$$\Delta t = W_{\text{heat}} / W = 101,820 / 4.8 = 5.90$$

$$5.90$$

6-111 - b)

$$\text{Cost} = (w)(\text{price}) = (4.4)(5.5)(0.11)$$

$$\begin{array}{r} -\$3.11 \\ \hline 3.11 \end{array}$$

$$c) - \text{New} = (Q_{it})(\text{price}) = (1.32 \cdot 10^6) \left(\frac{1}{2000} \right) (0.11)$$

$$Q_{it} = 55,000 / (24) = \frac{55,000}{1.32 \cdot 10^6}$$

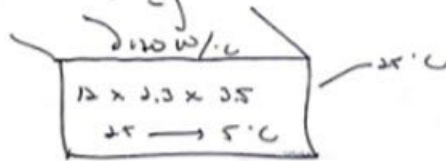
$$\begin{array}{r} 2440.3 \\ \hline 40.3 \end{array}$$

6-142

Known: $T_L = 25^\circ\text{C}$, $T_H = 5^\circ\text{C}$, $m = 4 \times 2.3 \times 3.5$,
 $W = 120\text{ W}$, $\rho = 1.2\text{ kg/m}^3$

Find: Determine how long it will take for a system with a refrigeration capacity of 120 W to freeze this trout.

Schematic:



Assumptions: You will need to be find the heat, Q , for both air and surrounding in the problem

Properties: All values needed to solve the problem are known. Only value needed is the time and heat value Q .

9/10

Analysis: $c_p = 1.005\text{ kJ/kg}^\circ\text{C}$
 $\rho = 1.2\text{ kg/m}^3$

$$m = \rho V = 1.2 (12 \times 2.3 \times 3.5) = 115.9$$

$$Q = mc_p \Delta T = (115.9)(1.005)(25 - 5) = 2329.9$$

$$Q = UA(T_L - T_H)$$

$$UA = 120\text{ W/C} = \frac{(120)(10)}{1000} = 1.2$$

$$T_L = 25^\circ\text{C}$$

$$T_H = (25 + 5)/2 = 15^\circ\text{C}$$

$$\Delta t = Q_0 / (QA - Q) = 2329.9 / (12 - 1.2) = 3.96$$

3.96

Units?

AVERAGE

use given format Chapter 6 Homework

6.16

8/10

$$\eta = 35\% = 0.35$$

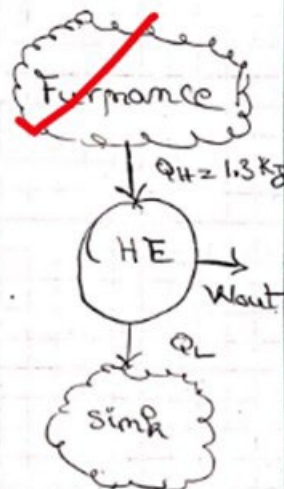
$$Q_H = 1.3 \text{ KJ}$$

The work produce

$$\eta = \frac{W_{out}}{Q_H} \Rightarrow W_{out} = \eta \times Q_H$$

$$W_{out} = 1.3 \text{ KJ} \times 0.35 = 0.455 \text{ KJ}$$

$$W_{out} = 0.455 \text{ KJ}$$



6.23

$$\begin{aligned}h &= 44,000 \text{ kJ/kg} \\ \dot{W}_{\text{net}} &= 55 \text{ kW} \\ \rho &= 0.8 \text{ g/cm}^3\end{aligned}$$

8/10

$$\begin{aligned}\dot{V} &= 22 \text{ ft}^3/\text{h} \times \left(\frac{1 \text{ h}}{3600 \text{ s}}\right) \times \left(\frac{1000 \text{ cm}^3}{1 \text{ ft}^3}\right) \\ &= 6.11 \text{ cm}^3/\text{s}\end{aligned}$$

mass flow rate

$$\begin{aligned}\dot{m} &= \dot{V} \times \rho \\ &= 6.11 \times 0.8 \\ &= 4.888 \text{ g/s} = 0.004888 \text{ kg/s}\end{aligned}$$

determine the efficiency

$$\eta = \frac{\dot{W}_{\text{net}}}{\dot{Q}_{\text{in}}}$$

$$\begin{aligned}\dot{Q}_{\text{in}} &= \dot{m} \times h \\ &= 0.004888 \times 44,000\end{aligned}$$

$$\dot{Q}_{\text{in}} = 214.72 \text{ kJ/s} = 214.72 \text{ kW}$$

$$\eta = \frac{55 \text{ kW}}{214.72 \text{ kW}} = 0.2561$$

$$\Rightarrow \boxed{\eta = 25.61\%}$$

6.25

$$\dot{W}_{\text{net}} = 2.800 \text{ W}$$

$$\eta = 32\%$$

9/10

$$h = 28000 \text{ kJ/kg}$$

$$p = 12 \text{ kg air/kg fuel}$$

a.) The coal consumed in a 24 h

$$\eta = \frac{W_{\text{out}}}{Q_{\text{in}}} \Rightarrow \dot{Q}_{\text{in}} = \frac{1}{\eta} \cdot W_{\text{out}}$$

$$\dot{Q}_{\text{in}} = \frac{2800}{0.32} = 8750 \text{ W}$$

$$\dot{Q}_{\text{in}} = 8750 \times 10^3 \text{ W}$$

mass flow rate of the fuel

$$\dot{Q}_{\text{in}} = \dot{m}_{\text{fuel}} \cdot h$$

$$\dot{Q}_{\text{in}} = \dot{m}_{\text{fuel}} \cdot h$$

$$\Rightarrow \dot{m}_{\text{fuel}} = \frac{\dot{Q}_{\text{in}}}{h}$$

$$\Rightarrow \dot{m}_{\text{fuel}} = \frac{8750 \times 10^3}{28000} = 312.5 \text{ kg/s}$$

$$\begin{aligned}
 m_{\text{coal}} &= \dot{m}_{\text{fuel}} \times t \\
 &= 33.48 \times 24 \times 3600 \\
 &= 2.89 \times 10^6 \text{ kg}
 \end{aligned}$$

$$\boxed{m_{\text{coal}} = 2.89 \times 10^6 \text{ kg}}$$

b.) The rate of air flowing through the furnace

$$\beta = \frac{\dot{m}_{\text{air}}}{\dot{m}_{\text{fuel}}} \Rightarrow \dot{m}_{\text{air}} = \beta \cdot \dot{m}_{\text{fuel}}$$

$$\dot{m}_{\text{air}} = 12 \times 33.48$$

$$\dot{m}_{\text{air}} = 401.76 \text{ kgs}$$

$$\boxed{\dot{m}_{\text{air}} = 401.76 \text{ kgs}}$$

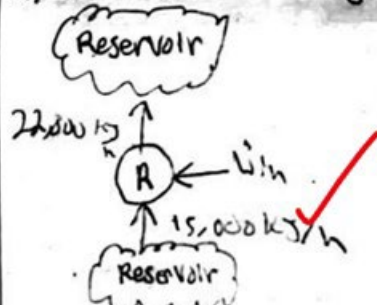
6.43

HW 6

Statement: A food refrigerator is to provide a 15,000-KJ/h cooling effect while rejecting 22,000 KJ/h of heat. Calculate the COP of this refrigerator.

Known: 15,000 KJ/h of cooling, 22,000 KJ/h of heat

Schematic



9/10

Properties: Need $\dot{W}_{net}$

Analysis: $\dot{W}_{net} = 22,000 - 15,000 = 7,000 \text{ kJ/h}$

Not clearly readable

$$COP = \frac{Q_c}{W_{net}} = \frac{15,000}{7,000} = \boxed{2.14}$$

2/2

6-53

HW 6

Statement

A refrigerator is used to cool water from 23° to 5°C in a continuous manner. The heat rejected in the condenser is 570 kJ/min and the power is 2.65 kW . Determine the rate at which water is cooled in L/min and the COP of the refrigerator. The specific heat of water is $4.18\text{ kJ/kg}\cdot^\circ\text{C}$ and its density is 1 kg/L .

Known

Find

Properties

COP, and rate of water cooled

Find the rate of rejected heat

7/10

Analysis

$$\dot{Q}_H = \frac{570000}{60} = 9500\text{ W}$$

$$\text{COP} = \frac{9500 - 2650}{2650} = \boxed{2.585} \quad \checkmark \text{ Show formulae}$$

$$\dot{Q}_C = 2.585(2650) = 6850.25\text{ W}$$

$$\frac{V}{t} = \frac{6850.25}{(1000)(4.186)(18)} = 9.091 \times 10^{-5}\text{ m}^3/\text{s}$$

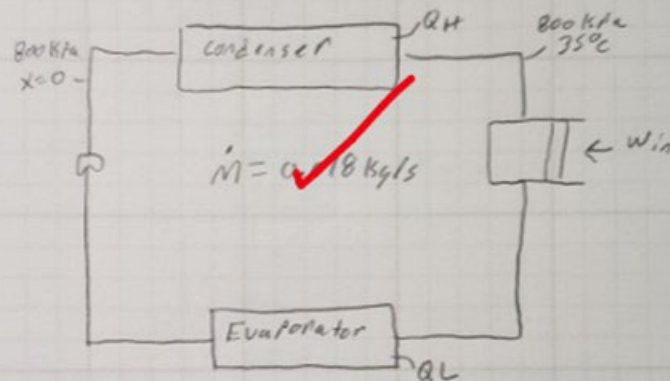
$$(9.091 \times 10^{-5}\text{ m}^3/\text{s}) \left(\frac{1\text{ L}}{10^{-3}\text{ m}^3} \right) \left(\frac{60\text{ s}}{1\text{ min}} \right) = \boxed{5.454\text{ L/min}}$$

Statement: Refrigerant-134a enters the condenser of a residential heat pump at 800 kPa and 35°C at a rate of 0.018 kg/s and leaves at 800 kPa as a saturated liquid. If compressor consumes 1.2 kW of power, determine (a) the COP of the heat pump and (b) the rate of heat absorption from the outside air.

Known: Pressure, 800 kPa; Temp., 35°C; Mass flow, 0.018; Power, 1.2 kW.

Find: COP of heat pump and heat absorption. 10/10

Schematic:



Assumption: Need to find h_1 and h_2 to solve.

Properties: $h_1 = 271.24 \text{ kJ/kg}$
 $h_2 = 95.46 \text{ kJ/kg}$

Analysis: $E_{in} = E_{out}$

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

$$= 0.018(271.24 - 95.46)$$

$$Q_H = 3.164 \text{ kW}$$

$$(a) \text{ COP}_{HP} = \frac{Q_H}{W_{in}}$$

$$= \frac{3.164}{1.2}$$

$$\boxed{\text{COP}_{HP} = 2.64}$$

$$(b) Q_L = Q_H - W_{in}$$

$$= 3.164 - 1.2$$

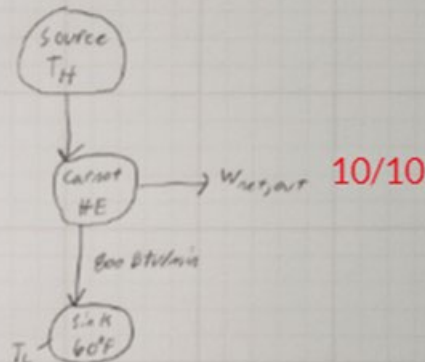
$$\boxed{Q_L = 1.963 \text{ kW}}$$

Statement: Carnot cycle has a thermal efficiency of 75%. The waste heat from this engine is rejected to a nearby lake at 60°F at a rate of 800 Btu/min. Determine (a) the power output of the engine and (b) the temp. of the source.

Known: T_L , 60°F; Flow rate, 800 Btu/min; Efficiency, 75%

Find: power output and T_H

Schematic:



Assumption: None

Properties: All are known

Analysis:

$$(a) \eta = \frac{W}{Q_H} = \frac{Q_H - Q_L}{Q_H} \quad W_{net} = \eta \cdot Q_H \quad 18 \text{ ft/min} = 0.02354 \text{ hp}$$

$$\eta = 1 - \frac{Q_L}{Q_H} \quad W_{net} = 0.75 \cdot 7200 \text{ Btu/min} = 2400 \text{ Btu/min}$$

$$0.75 = 1 - \frac{800}{Q_H} \quad 2400 \cdot 0.02354$$

$$Q_H = \frac{800}{1 - 0.75} \quad W_{net} = 56.544 \text{ hp}$$

$$Q_H = 3200 \text{ Btu/min}$$

$$(b) \eta = 1 - \frac{T_L}{T_H}$$

$$0.75 = 1 - \frac{60 + 460}{T_H}$$

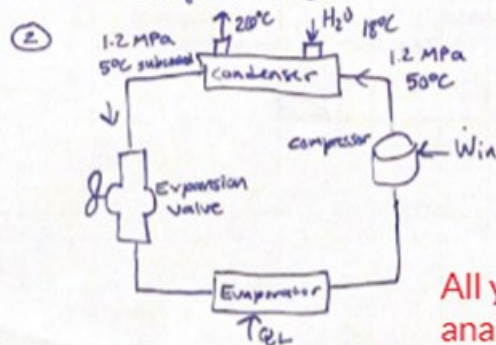
$$T_H = \frac{520}{0.25}$$

$$T_H = 2080 \text{ R}$$

6.107

REF. 134a $T_1 = -35^\circ\text{C}$

- Determine the mass flow rate
- refrigeration load
- COP
- min. power input to the compressor for the same refrigeration load



2/10

All your numbers in the analysis are wrong values

$$h_1 = 275.52 \quad h_2 = 263.80? \quad h'_1 = 109.07 \quad h'_2 = 75.58 \text{ kg}$$

$$m_2 \times (h_1 - h_2) = m_1 (h'_1 - h'_2)$$

$$M_E(295.52 - 263.80) = .25(109.07 - 75.52)$$

a) mass flow rate = 0.714 kg/s How?

$$T = -35^{\circ}\text{C} \quad h_1 = 232.35 \text{ kJ/kg}$$

$$Q_L = .714(263.80 - 232.35) = 6) \boxed{22.52 \text{ XJ/s}}$$

c) $COP = \frac{Q_L}{W_{in}} = \frac{22.52}{3.3} = \boxed{6.82}$

d) $COP_{max} = \frac{1}{\left[\frac{T_H}{T_L} - 1\right]} = 4.249$ Less than 50
therefore $W_{in, min} = 3.3 \text{ kW}$

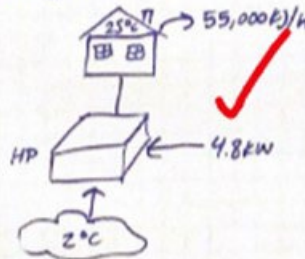
6.111

- ① Carnot heat pump used to heat a house and maintain it at 25°C in winter. When avg. temp is 2°C house loses heat at rate $55,000 \text{ kJ/h}$. If heat pump consumes 4.8 kW of power while operating

10/10

- a) how long it ran on that day
b) heating cost, price $\$0.11/\text{kWh}$
c) heating cost if resistance heating used

②



$$a) \text{COP} = \frac{T_H}{T_H - T_L} = \frac{(25+273)}{(25+273) - (2+273)} = 12.9565$$

$$12.9565 = \frac{55000}{W_{\text{req}}} = 4245 \text{ kJ/h}$$

$$4245 \times 24 = 101879 \text{ kJ} \quad P = \frac{W_{\text{req}}}{t_{\text{pump}}}$$

$$4.8 = \frac{101879}{t_{\text{pump}}} = t_{\text{pump}} = 21225 \text{ s}$$

$$(21225 \text{ s}) \times \left(\frac{1 \text{ h}}{3600 \text{ s}}\right) = \boxed{5.9 \text{ h}} \quad a$$

$$b) \text{Cost} = (\text{Power pump})(t_{\text{pump}})(\text{rate}) = (4.8)(5.9)(.11) = \boxed{\$3.115}$$

$$c) \dot{Q}_H = 55,000 \text{ kJ/h} = 55000 \text{ kJ/h} \left(\frac{1 \text{ h}}{3600 \text{ s}}\right) = 15.278 \text{ kW}$$

$$\text{Cost} = (\dot{Q}_H)(\Delta T)(\text{Rate})$$

$$(15.278 \text{ kW})(24 \text{ h})(.11) = \boxed{\$40.93}$$

$$6-142$$

Use given format

$$12\text{ m} \cdot 2.3\text{ m} \cdot 3.5\text{ m}$$

$$m = \rho V$$

$$= 1.2 (12 \cdot 2.3 \cdot 3.5)$$

$$m = 115.92\text{ kg}$$

$$C_p = 1.005\text{ kJ/kg}$$

$$\rho = 1.2\text{ kg/m}^3$$

$$Q = m C_p \Delta T$$

$$= 115.92 \cdot 1.005 \cdot \Delta T$$

$$= 115.92 \cdot 1.005 (25 - 5)$$

$$Q = 2329.99$$

Find the properties of ~~the~~ air at various temperatures and the energy balance and determine the time taken for refrigerator.

$$Q_{\text{avg}} = V A (T_2 - T_{\text{avg}})$$

$$T_{\text{avg}} = \frac{25 + 5}{2} = 15^\circ\text{C}$$

8/10

$$V A = 120\text{ W}$$

$$T_2 = 25^\circ\text{C}$$

$$Q_{\text{avg}} = 120 (25 - 15)$$

$$= 1200\text{ W}$$

$$= 1.2\text{ kW}$$

what equation is that?

$$\Delta T = \frac{Q_1}{Q - Q_{\text{avg}}}$$

$$Q = 11\text{ kW}$$

$$Q_{\text{avg}} = 1.2\text{ kW}$$

$$Q_1 = 2329.99$$

$$\Delta T = \frac{2329.99}{11 - 1.2} = 237.75$$

$$\Delta t = 237.75 \cdot \frac{1}{60} = 3.96\text{ min}$$

$$\Delta t = 3.96\text{ min}$$

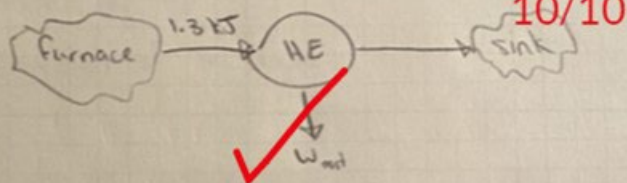
BELOW AVERAGE

G.16(30%): A heat engine has a total heat input of 1.3 kJ and a thermal efficiency of 35%. How much work will it produce?

Known: $Q_{in} = 1.3 \text{ kJ}$
 $\eta_{th} = 35\%$

Find: W_{out}

Schematic:



Assumptions: heat input is the only E coming in

Properties: All needed properties are known

Analysis:

$$35\% / 100 = 0.35$$

$$1.3 \times 0.35 = \boxed{0.445 \text{ kJ}}$$

comments: efficiency is 35%, so W_{out} will be 35% of any E_{in}

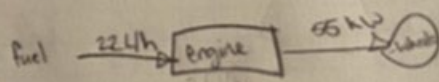
C.23(309): An automobile engine consumes fuel at a rate of 22 L/h and delivers 55 kW of power to the wheels. If the fuel has a heating value of 44,000 kJ/kg and density of 0.8 g/cm³, determine the efficiency of this engine.

10/10

Known: $\rho = 0.8 \text{ g/cm}^3$
 $P = 55 \text{ kW}$
 $H = 44,000 \text{ kJ/kg}$

find: efficiency (η) of the engine

schematic:



assumptions: fuel is the only form of energy the engine uses

Properties: All needed properties are known

Analysis:

$$V_{\text{consumed per second}} = \frac{22}{60 \times 60} = 6.1 \times 10^{-3} = 6.1 \text{ cm}^3$$

$$m_{\text{consumed per second}} = V\rho = (6.1)(0.8) = 4.88 \text{ g} = 0.00488 \text{ kg}$$

$$Q_{\text{fuel per second}} = HM = (44,000)(0.00488) = 215.07 \text{ kJ}$$

$$55 \text{ kW} = 55 \text{ kJ/s}$$

$$\epsilon = \frac{55}{215.07} = 0.256 \times 100 = 25.6\%$$

comments: 25.6% is around the average efficiency of a car engine

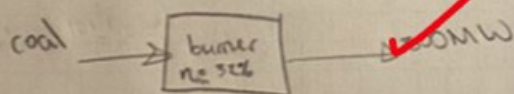
6.25(30A): A coal-burning steam power plant produces a net power of 300 MW with an overall thermal efficiency of 32%. The actual gravimetric air-fuel ratio in the furnace is calculated to be 12 kg air/kg fuel. The heating value of the coal is 28,000 kJ/kg. Determine (a) the amount of coal consumed during a 24-hour period and (b) the rate of air flowing through the furnace.

Known: $P_{\text{net}} = 300 \text{ MW}$
 $\eta_{\text{th}} = 32\%$
 air-fuel ratio = 12 kg air/kg fuel
 $H = 28,000 \text{ kJ/kg}$

10/10

Find: a) amt coal consumed during a 24 hour period
 b) rate of air flowing through the furnace

Schematic:



assumptions: Coal is the only energy being supplied for burning

Properties: All needed properties are known

Analysis: a) $\eta_{\text{th}} = \frac{\dot{W}_{\text{net}}}{\dot{Q}_{\text{in}}} = \frac{300}{0.32} = 937.5 \text{ MW} = 937,500 \text{ kW}$

$$\dot{Q}_{\text{in}} = \dot{m}_f \cdot H$$

$$\dot{m}_f = \frac{\dot{Q}_{\text{in}}}{H} = \frac{937,500}{28,000} = 33.48 \text{ kg/s}$$

$$33.48 \times 24 \text{ hr} \times 3600 \text{ s} = 2.84 \times 10^6 \text{ kg}$$

b) $A/F = \frac{\dot{m}_{\text{air}}}{\dot{m}_{\text{fuel}}}$

$$\dot{m}_{\text{air}} = \frac{A}{F} \times \dot{m}_{\text{fuel}} = 12 \times 33.48 = 401.76 \text{ kg/s}$$

comments: This is an entire power plant, which explains why the numbers are so big

Q-43 Problem Statement

A food refrigerator is to provide a $15,000 \text{ kJ/h}$ cooling effect while rejecting $22,000 \text{ kJ/h}$ of heat. Calculate the COP of this refrigerator.

Known

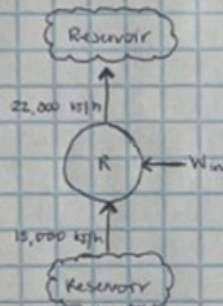
Rejected heat $Q_H = 22,000 \text{ kJ/h}$

Cooling effect $Q_L = 15,000 \text{ kJ/h}$

Find

Calculate the efficiency of the refrigerator

Schematic



Properties

All needed properties are known

Analysis

$$\text{COP}_R = \frac{\text{desired output}}{\text{Required input}}, \quad \text{COP}_R = \frac{Q_L}{W_{\text{net}}}$$

Solution Plan

Compute COP_R from equation

$$W_{\text{net}} = 22,000 - 15,000 \quad \text{therefore} \quad \text{COP}_R = \frac{Q_L}{W_{\text{net}}} = \frac{15,000}{7,000}$$

$$\boxed{\text{COP}_R = 2.14}$$

10/10

6-53

A refrigerator used to cool water from 22 to 5°C in a continuous manner. The heat rejected in the condenser is 570 kJ/min and the power is 2.65 kW.

Find the rate at which water is cooled.

Known:

22 to 5°C

Heat rejected is 570 kJ/min

power = 2.65 kW

specific heat = 4.18 kJ/kg

Solution:

$$570 \times 10^3 \left(\frac{1 \text{ min}}{60 \text{ s}} \right)$$

$$\text{COP} = \frac{q_c}{w} = \frac{q_h - w}{w}$$

$$\frac{7500 \text{ W} - 2650 \text{ W}}{2650 \text{ W}}$$

$$= 2.88$$

$$2.88 (2650)$$

$$= 6950.2 \text{ J}$$

$$\frac{q}{t} = \frac{m c \Delta T}{t}$$

$$\frac{6950.2 \text{ J}}{1000 \text{ kg/m}^3 (4186 \text{ J/kg}^\circ\text{C}) (22-5)}$$

$$7.0714 \times 10^{-4}$$

$$= 7.0714 \times 10^{-5} \left(\frac{1 \text{ L}}{10^{-3} \text{ m}^3} \right) \left(\frac{60 \text{ s}}{1 \text{ min}} \right)$$

=

$$\boxed{5.96 \text{ L/min}}$$

Unreadable work

2/10

6-84E

A heat engine is operating on a Carnot cycle and has a t.e. of 75%. The waste heat from this engine is rejected to a nearby lake at 60°F and at a rate of 800 Btu/min.

Step 1: Known: $\eta = 75\%$

$$T_L = 60^\circ\text{F}$$

$$Q_L = 800 \text{ Btu/min}$$

$$\eta = \frac{W_{\text{net}}}{Q_H}$$

$$\eta = \frac{Q_H - Q_L}{Q_H}$$

$$\eta = 1 - \frac{Q_L}{Q_H}$$

$$0.75 = 1 - \frac{800}{Q_H}$$

$$Q_H = \frac{800}{1 - 0.75}$$

$$Q_H = 3200 \text{ Btu/min}$$

Step 2: Power output determined from thermal efficiency

$$W_{\text{net}} = \eta Q_H$$

$$W_{\text{net}} = (0.75)(3200)$$

$$= 2400 \text{ Btu/min}$$

$$1 \text{ Btu/min} = 0.02356 \text{ hp}$$

$$W_{\text{net}} = 2400 \times 0.02356$$

$$W_{\text{net}} = 56.54 \text{ hp}$$

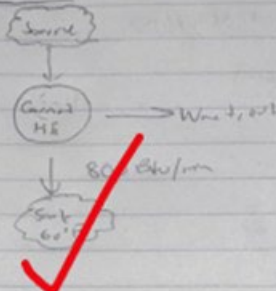
Step 3:

$$\eta = 1 - \frac{T_L}{T_H}$$

$$0.75 = 1 - \frac{60 + 460}{T_H}$$

$$T_H = 2080 \text{ R}$$

Schematic:



10/10

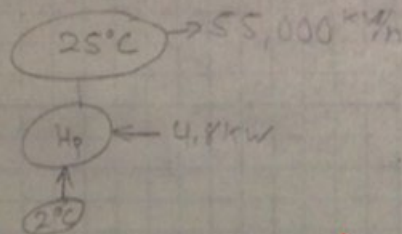
Problem 6.107 not done 0/10

Problem 6-111: A Carnot heat pump is being used to heat a house and maintain it at 25°C in winter. On a day when the average outdoor temperature remains about 2°C , the house is estimated to lose heat at a rate of $55,000 \text{ kJ/h}$.

Known: $T_H = 25^{\circ}\text{C} = 298.15 \text{ K}$, $W_{\text{HP}} = 4.8 \text{ kW}$, $Q_H = 55,000 \text{ kJ/h} = 152,800 \text{ kJ} = 132,000 \text{ kJ}$, $T_L = 2^{\circ}\text{C} = 275.15 \text{ K}$

Find: A.) how long the heat pump was on, B.) Total cost, C.) The heating cost for that day

Schematic:



10/10

Assumptions: Convert $55,000 \text{ kJ/h}$ into a day of power. Solve for COP_{HP} and W_{net} in order to find what is needed. Also convert

Properties: All properties are known

Analysis: $\text{COP}_{\text{HP}} = \frac{1}{1 - \left(\frac{T_L}{T_H}\right)} = \frac{1}{1 - \left(\frac{275.15}{298.15}\right)} = 12.96$

$W_{\text{net}} = \frac{Q_H}{\text{COP}_{\text{HP}}} = \frac{132,000 \text{ kJ}}{12.96} = 101,852 \text{ kJ}$

A.) $\Delta T = \frac{W_{\text{net}}}{W_{\text{HP}}} = \frac{101,852 \text{ kJ}}{4.8 \text{ kW}} = \frac{21219.2 \text{ s}}{3600 \text{ s}} = 5.9 \text{ h}$

B.) $\text{Cost} = (W \Delta T) \text{ price} = 4.8 \text{ kW} \times 5.9 \text{ h} \times \$11 = \$3.12$

C.) $\text{Cost for the day} = Q_H (\$11) = 132,000 \left(\frac{1 \text{ kW}}{3600}\right) (\$11) = \$40.3$

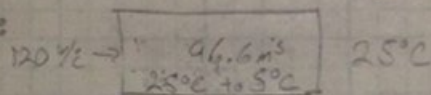
Problem 6-142: The cargo space of a refrigerated truck whose inner dimensions are $(12 \times 2.3 \times 3.5) \text{ m}$ is to be precooled from 25°C to an average temperature of 5°C . The construction of the truck is such that a transmission heat gain occurs at a rate of $120 \text{ W/}^\circ\text{C}$.

known: $V = (12 \times 2.3 \times 3.5) \text{ m} = 96.6 \text{ m}^3$, $T_2 = 25^\circ\text{C}$, $T_1 = 5^\circ\text{C}$

Find: If the ambient temperature is 25°C , determine how long it will take for a system with a refrigeration capacity of 11 kW to precool this truck

10/10

Schematic:



Assumptions:

Properties: $C_p = 1.005 \text{ kJ/kg}^\circ\text{C}$, $\rho = 1.2 \text{ kg/m}^3$, $T_i = 15^\circ\text{C}$

Analysis: Find the heat transfer for when the truck is precooled and for when the temperature is ambient

$$m = \rho V = 1.2 \text{ kg/m}^3 (96.6 \text{ m}^3) = 115.92 \text{ kg}$$

$$Q_{\text{cool}} = m C_p (T_2 - T_1) = (115.92 \text{ kg}) (1.005 \text{ kJ/kg}^\circ\text{C}) (25 - 5)$$

$$Q_{\text{cool}} = 2329.9 \text{ kJ}$$

$$Q_{\text{amb}} = UA(T_F - T_i) = 120 \text{ W/}^\circ\text{C} (25^\circ\text{C} - 15^\circ\text{C}) = \frac{1200 \text{ W}}{1000 \text{ kJ/s}}$$

$$Q_{\text{amb}} = 1.2 \text{ kJ/s}$$

Use COP_{ref} to find the time

$$\Delta t = \frac{2329.9 \text{ kJ}}{11 \text{ kJ/s} - 1.2 \text{ kJ/s}} = 237.7 \text{ s}$$

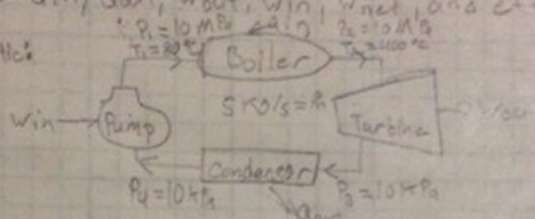
What question is this??

shown in Figure 6-10? Boiler inlet: $P_1 = 10 \text{ MPa}$, $T_1 = 80^\circ\text{C}$; Boiler exit: $P_2 = 10 \text{ MPa}$, $T_2 = 400^\circ\text{C}$; Turbine outlet: $P_3 = 10 \text{ kPa}$, saturated vapor; Condenser outlet: $P_4 = 10 \text{ kPa}$, saturated liquid.

Known: $P_1 = 10 \text{ MPa}$, $T_1 = 80^\circ\text{C}$, $P_2 = 10 \text{ MPa}$, $T_2 = 400^\circ\text{C}$, $\dot{m} = 5 \text{ kg/s}$

Find: $\dot{Q}_{in}$, $\dot{Q}_{out}$, $\dot{W}_{out}$, $\dot{W}_{in}$, $\dot{W}_{net}$, and efficiency of cycle.

Schematic:



Assumptions: The system is a steady state, $\dot{E}_2 - \dot{E}_1 = 0$

Properties: $h_1 = 342.94 \text{ kJ/kg}$, $h_2 = 3097.5 \text{ kJ/kg}$

Analysis: P_3 is a saturated vapor and P_4 is a saturated liquid.

$$P_3 = h_3 = 2725.5 \text{ kJ/kg}$$

$$P_4 = h_4 = 1407.8 \text{ kJ/kg}$$

Turbine

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{m}h_2 = \dot{m}h_3 + \dot{W}_{out}$$

$$\dot{W}_{out} = \dot{m}(h_2 - h_3)$$

$$\dot{W}_{out} = 5 \text{ kg/s} (3097.5 - 2725.5) \text{ kJ/kg}$$

$$\dot{W}_{out} = 1860 \text{ kW}$$

Pump

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{W}_{in} + \dot{m}h_4 = \dot{m}h_1$$

$$\dot{W}_{in} = \dot{m}(h_1 - h_4)$$

$$\dot{W}_{in} = 5 \text{ kg/s} (342.94 - 1407.8) \text{ kJ/kg}$$

$$\dot{W}_{in} = -5324.3 = 5324.3 \text{ kW}$$

$$\eta = \frac{\dot{W}_{out}}{\dot{W}_{in}} = \frac{1860 \text{ kW}}{5324.3 \text{ kW}} = 0.35$$

Boiler

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{Q}_{in} + \dot{m}h_1 = \dot{m}h_2$$

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

$$\dot{Q}_{in} = 5 \text{ kg/s} (3097.5 - 342.94) \text{ kJ/kg}$$

$$\dot{Q}_{in} = 13772.8 \text{ kW}$$

Condenser

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{m}h_3 = \dot{Q}_{out} + \dot{m}h_4$$

$$\dot{Q}_{out} = \dot{m}(h_3 - h_4)$$

$$\dot{Q}_{out} = 5 \text{ kg/s} (2725.5 - 1407.8) \text{ kJ/kg}$$

$$\dot{Q}_{out} = 6588.5 \text{ kW}$$

**THERMODYNAMICS I
FALL 2021**

HOMEWORK 7

TOPICS COVERED IN HOMEWORK 7

Homework 7 covered the topics:

ENTROPY

HOMEWORK #7 QUESTIONS

**Formal: Problems 7.24, 7.30E, 7.36, 7.51 ,
7.60, 7.141, 7.216**

ABOVE AVERAGE

Homework # 7

Problem # 7.24

$$T = 25^{\circ}\text{C} = 298.15\text{ K}$$

10/10

$$W = -40\text{ kW}$$

Determine the rate of entropy change of the air

$$E_{in} - E_{out} = E_2 - E_1$$

$$\Rightarrow E_{in} - E_{out} = 0$$

$$\Rightarrow Q - W = 0$$

$$\Rightarrow Q = W = -40\text{ kW}$$

$$\therefore ds = Q/T$$

$$\Delta s = \frac{-40}{298.15} = -0.134\text{ kW/K}$$

$$\Delta s = -0.134\text{ kW/K}$$

Problem # 7.30E

$$\begin{aligned} T_1 &= 100^\circ\text{F} \\ P_1 &= 100\text{ psia} \end{aligned} \quad \left\{ \begin{aligned} s_1 &= 0.229 \text{ Btu/lbm} \cdot \text{R} \\ u_1 &= 109.45 \text{ Btu/lbm} \end{aligned} \right.$$

$$P_2 = 10\text{ psia} \quad \left\{ \begin{aligned} s_f &= 0.00719 \text{ Btu/lbm} \cdot \text{R} \\ s_{fg} &= 0.22206 \text{ Btu/lbm} \cdot \text{R} \end{aligned} \right. \quad 10/10$$

$$P_2 = 10\text{ psia} \quad \left\{ \begin{aligned} u_f &= 3.315 \text{ Btu/lbm} \\ u_{fg} &= 87.45 \text{ Btu/lbm} \end{aligned} \right.$$

* The total heat transfer

There is no heat transfer $Q = 0$ Btu because the R-134a expanded isentropically in a closed system, so the process is reversible. There is no area under T-s curve.

* The work produced

$$E_{in} - E_{out} = E_2 - E_1$$

$$Q - W_{out} = m u_2 - m u_1 \quad Q = 0$$

$$\Rightarrow W_{out} = m(u_1 - u_2)$$

$$\Rightarrow W_{out} = m(u_1 - u_2)$$

At final state $P_2 = 10\text{ psia}$

$$s_2 = s_1 = 0.229 \text{ Btu/lbm} \cdot \text{R}$$

$$s_2 = s_f + x s_{fg}$$

$$0.229 = 0.00742 + x(0.22206)$$

$$\Rightarrow x = 0.998$$

$$u_2 = u_f + x u_{fg}$$

$$= 3.315 + (0.998) \times (87.45)$$

$$u_2 = 90.45 \text{ Btu/lbm}$$

$$W_{\text{out}} = \dot{m} \times (109.25 - 90.45)$$

$$W_{\text{out}} = 19 \text{ Btu}$$

Problem # 7.36

$$V = 0.05 \text{ m}^3$$

$$P_1 = 0.8 \text{ MPa}$$

$$P_2 = 0.4 \text{ MPa}$$

10/10

a) determine the final temperature
At $P_1 = 0.8 \text{ MPa}$

$$v_1 = v_g = 0.025621 \text{ m}^3/\text{kg}$$

$$u_1 = u_g = 246.79 \text{ kJ/kg}$$

$$s_1 = s_g = 0.91835 \text{ kJ/kg} \cdot \text{K}$$

$$m = \frac{V}{v_1} = \frac{0.05 \text{ m}^3}{0.025621 \text{ m}^3/\text{kg}} = 1.95 \text{ kg}$$

$$m = 1.95 \text{ kg}$$

At $P_2 = 0.4 \text{ MPa}$

$$s_f = 0.24761 \text{ kJ/kg} \cdot \text{K}$$

$$s_{fg} = 0.67929 \text{ kJ/kg} \cdot \text{K}$$

$$u_f = 63.62 \text{ kJ/kg}$$

$$u_{fg} = 171.45 \text{ kJ/kg}$$

Process is reversible adiabatic

$$s_2 = s_1$$

$$s_2 = s_f + x_2 (s_{fg})$$

$$x_2 = \frac{s_2 - s_f}{s_{fg}}$$

$$= \frac{(0.91835 - 0.24761)}{0.67929}$$

$$= 0.9874$$

$$\mu_2 = \mu_f + x_2 \mu_{fg}$$

$$= 63.62 + (0.9874)(171.45)$$

$$= 232.91 \text{ kJ/kg}$$

$$\mu_2 = 232.91 \text{ kJ/kg}$$

$$p_2 = 0.4 \text{ MPa}$$

$$T_2 = T_{sat} = 8.91^\circ\text{C}$$

$$T_2 = 8.91^\circ\text{C}$$

b) work done by the refrigerant

$$E_{in} - E_{out} = E_2 - E_1$$

$$Q - W_{out} = m(\mu_2 - \mu_1)$$

$$Q = 0$$

$$\Rightarrow W_{out} = m(\mu_1 - \mu_2)$$

$$= 1.952 \times (246.79 - 232.91)$$

$$W_{out} = 27.05 \text{ kJ}$$

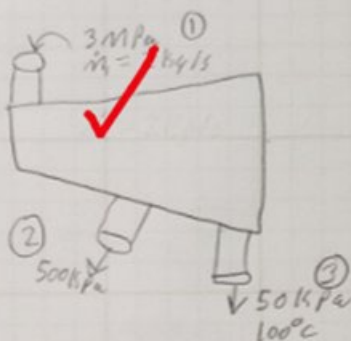
Statement: An isentropic steam turbine processes 2 kg/s of steam at 3 MPa, which is exhausted at 50 kPa and 100°C. Five percent of this flow is diverted for feedwater heating at 500 kPa. Determine the power produced by this turbine in kW.

10/10

Known: Mass flow, 2 kg/s; pressure (1, 2, 3), 3 MPa, 500 kPa, 50 kPa; Temp. (3), 100°C.

Find: Power in kW

Schematic:



Assumption: None

Properties: $h_3 = 2682.4$ (From table); $s_1 = s_2 = s_3 = 7.6953$

Analysis:

$$\dot{m}_1 = 2 \text{ kg/s}$$

$$\dot{m}_2 = \frac{5}{100} \cdot 2 = 0.1 \text{ kg/s}$$

$$\dot{m}_3 = \dot{m}_1 - \dot{m}_2 = 1.9 \text{ kg/s}$$

T_2 at 500 kPa

$$\frac{400 - T_2}{400 - 350} = \frac{7.7956 - 7.6953}{7.7956 - 7.6346}$$

$$T_2 = 368.85^\circ\text{C}$$

h_2 at $T_2 = 368.85^\circ\text{C}$

$$\frac{3272.4 - h_2}{3272.4 - 3168.1} = \frac{400 - 368.85}{400 - 350}$$

$$h_2 = 3207.42$$

T_1 at 3 MPa

$$\frac{700 - T_1}{700 - 600} = \frac{7.759 - 7.6953}{7.759 - 7.5103}$$

$$T_1 = 674.4^\circ\text{C}$$

h_1 at $T_1 = 674.4^\circ\text{C}$

$$\frac{3912.2 - h_1}{3912.2 - 3482.2} = \frac{700 - 674.4}{700 - 600}$$

$$h_1 = 3853.47$$

$$\text{Power} = (\dot{m}_1 h_1 - \dot{m}_2 h_2 - \dot{m}_3 h_3) = (2 \cdot 3853.47 - 0.1 \cdot 3207.42 - 1.9 \cdot 2682.4)$$

$$\text{Power} = 2289 \text{ kW}$$

7-141

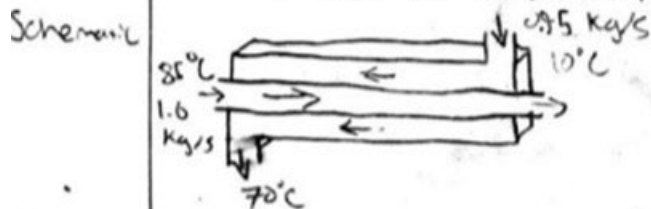
HW 7

statement Cold water ($C_p = 4.18 \text{ kJ/kg} \cdot ^\circ\text{C}$) leading to a shower enters a well-insulated, thin walled double-pipe counterflow heat exchanger at 10°C at a rate of 0.95 kg/s and is heated to 70°C by hot water ($C_p = 4.19 \text{ kJ/kg} \cdot ^\circ\text{C}$) that enters at 85°C at a rate of 1.6 kg/s . Determine (a) the rate of heat transfer and (b) the rate of entropy generation in the heat exchanger.

known $\dot{m}_c = 0.95 \text{ kg/s}$, $\dot{m}_h = 1.6 \text{ kg/s}$, $T_h = 85^\circ\text{C}$, $T_c = 10^\circ\text{C}$, $C_{p,c} = 4.18 \text{ kJ/kg} \cdot ^\circ\text{C}$, $C_{p,h} = 4.19 \text{ kJ/kg} \cdot ^\circ\text{C}$

Find The rate of heat transfer and the rate of entropy

Properties Find the rate of heat transfer



9/10

Analysis

$$\dot{Q} = \dot{m}_c (C_{p,c}) (T_2 - T_1)$$

$$\dot{Q} = 0.95 (4.18) (70 - 10)$$

$$\dot{Q} = 238.26 \text{ kW}$$

$$\dot{Q} = \dot{m}_h (C_{p,h}) (T_{h1} - T_{h2})$$

$$238.26 = 1.6 \cdot 4.19 (85 - T_{h2})$$

$$238.26 = 569.84 - 6.704 T_{h2}$$

$$-331.58 = -6.704 T_{h2}$$

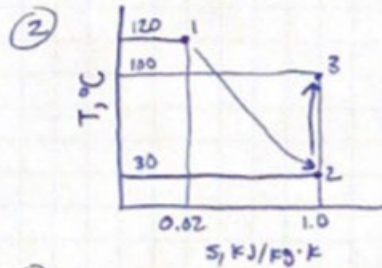
$$T_{h2} = 49.46^\circ\text{C}$$

$$S_{\text{gen}} = \dot{m}_c \cdot C_{p,c} \cdot \ln\left(\frac{T_2}{T_1}\right) + \dot{m}_h \cdot C_{p,h} \cdot \ln\left(\frac{T_{h2}}{T_{h1}}\right)$$

$$S_{\text{gen}} = 0.95 \cdot 4.18 \cdot \ln\left(\frac{70}{10}\right) + 1.6 \cdot 4.19 \cdot \ln\left(\frac{322.46}{358}\right)$$

$$S_{\text{gen}} = 0.0619 \text{ kW/K}$$

- 7-60
① Calculate the heat transfer, in kJ/kg.



10/10

- ③
- | | |
|---|--------------|
| $T_1 = 120^\circ\text{C} = 393\text{K}$ | $s_1 = 0.02$ |
| $T_2 = 30^\circ\text{C} = 303\text{K}$ | $s_2 = 1.00$ |
| $T_3 = 100^\circ\text{C} = 373\text{K}$ | $s_3 = 1.00$ |

$$q_{1-2} = T(s_2 - s_1) = \frac{393 + 303}{2} (1.00 - 0.02) = 341.04 \text{ kJ/kg}$$

$$q_{2-3} = T(s_3 - s_2) = \frac{303 + 373}{2} (1.00 - 1.00) = 0 \text{ kJ/kg}$$

$$q_{1-3} = q_{1-2} + q_{2-3} = 341 \text{ kJ/kg} + 0 \text{ kJ/kg} = 341 \text{ kJ/kg}$$

The heat transfer for the reversible steady-flow process 1-3 is 341 kJ/kg.

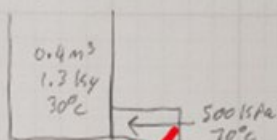
Problem 7.26

Statement: A 0.40 m^3 insulated piston-cylinder device initially contains 1.3 kg of air at 30°C . At this state, the piston is free to move. Now air at 500 kPa and 70°C is allowed to enter the cylinder from a supply line until the volume increases by 50% . Using constant specific heats at room temp., determine (a) the final temp., (b) the amount of mass that has entered, (c) the work done, and (d) the entropy.

Known: Volume, 0.4 m^3 ; mass of air, 1.3 kg ; temp. ($1, i$), 303°K , 303°C
Pressure (i), 500 kPa

Find: Final temp., mass entering, work done, and the entropy.

Schematic:



10/10

Assumption: None

Properties: $R = 0.287$ $C_p = 1.005$ $C_v = 0.718$
(From table)

Analysis:

$$P_1 = \frac{m_1 R T_1}{V_1} = \frac{1.3 \cdot 0.287 \cdot 303}{0.4} = 282.62 \text{ kPa}$$

$$V_2 = 1.5 \cdot V_1 = 0.6 \text{ m}^3$$

$$a) P_2 V_2 = m_2 R T_2$$

$$T_2 = \frac{282.62 \cdot 0.6}{1.8736 \cdot 0.287} = 315.3^\circ\text{K}$$

$$c) W = P(V_2 - V_1) = 282.62(0.6 - 0.4) = 56.52 \text{ kJ}$$

$$d) S_{gen} = m_1 C_p \ln\left(\frac{T_2}{T_1}\right) + m_2 C_p \ln\left(\frac{T_2}{T_i}\right) - m_1 R \ln\left(\frac{P_2}{P_1}\right) - m_2 R \ln\left(\frac{P_2}{P_i}\right) = 1.3 \cdot 1.005 \ln\left(\frac{315.3}{303}\right) + 0.5736 \cdot 1.005 \ln\left(\frac{315.3}{700}\right) - 1.3 \cdot 0.287 \ln\left(\frac{282.62}{303}\right) - 0.5736 \cdot 0.287 \ln\left(\frac{282.62}{500}\right) = 0.69736 \text{ kJ/K}$$

$$b) m_i = m_2 - m_1 \quad u = C_v \cdot T \quad h_i = C_p T_i$$

$$(m_2 u_2 - m_1 u_1) = h_i (m_2 - m_1) - W_{out}$$

$$(m_2 C_v T_2 - m_1 C_v T_1) = C_p T_i (m_2 - m_1) - W_{out}$$

$$C_v \left(\frac{P_2 V_2}{R} - \frac{P_1 V_1}{R} \right) = (m_2 - 1.3) \cdot 1.005 (303) - 56.52$$

$$\frac{0.717}{0.287} (0.6 - 0.4) 282.62 = (m_2 - 1.3) \cdot 1.005 (303) - 56.52$$

$$m_2 = 1.8736$$

$$m_i = 1.8736 - 1.3 = 0.5736 \text{ kg}$$

AVERAGE

Group 2

7-24

Given: 40 kW, 25°C, 20°C

Find: Entropy change in air

Schematic: N/A

10/10

Assumption: The table will be used to help solve this problem

Analysis:

Heat loss $m h_1 + W = m h_2 + Q_a$

$W = 40 \text{ kW}$

$Q_a = 298 \text{ K}$

$$\frac{-40}{298} = \boxed{-0.13422 \text{ kW/K}}$$

Comments: Heat loss formula was applied

Comp 2

7-3015

Given: 100 psia, 100°F, 10 psia

Find: The total heat transfer

Schematic: W/A

Assumption: The 134a table is going to be used

Analysis:

expanded isentropically in closed system so
Heat transfer is $Q = 0 \text{ Btu}$

Enthalpy

$$s_1 = 0.229$$

$$s_2 = 0.229$$

$$0.229 = 0.00942 + x(0.22206)$$

$$x = 0.998$$

$$u_1 = 109.45$$

$$3.315 + (0.998)(87.45) = 90$$

$$1(109.45 - 90.45)$$

$$W_{out} = 190 \text{ Btu}$$

10/10

Comments: Property tables were used

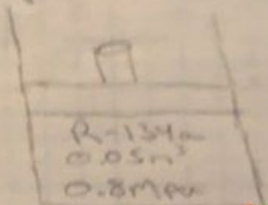
Group 2

7-36

Given: 0.05 m^3 , 0.8 MPa , 0.4 MPa

Find: final temp and work done

Schematic:



Assumption: This process may have constant volume

10/10

Analysis:

$$P_1 = 0.8 \text{ MPa}$$

$$V_1 = 0.0255$$

$$u_1 = 243.78$$

$$z_1 = 0.9066$$

$$P = 0.4$$

$$s_f = 0.2399 \quad u_f = 61.69$$

$$s_g = 0.9145 \quad u_g = 231.97$$

$$T_{\text{sat}} = 8.13^\circ \text{C}$$

$$0.9066 = 0.2399 + x(0.9145 - 0.2399)$$

$$x = 0.9882$$

$$61.69 + 0.9882(231.91 - 61.91)$$

$$229.976$$

$$\frac{V_1}{V_1} (u_1 - u_2) = \frac{0.05}{0.025} (243.78 - 229.976)$$

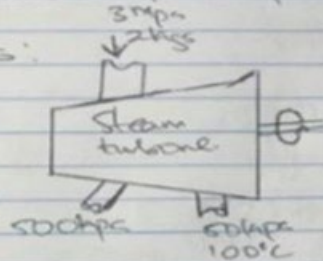
$$W = 27.066$$

7.51

Given: $m_1 = 2 \text{ kg/s}$, $m_2 = \frac{5}{100} \times 2 = 0.1 \text{ kg/s}$
 $P_1 = 3 \text{ MPa}$
 $P_2 = 500 \text{ kPa}$, $m_3 = m_1 - m_2 = 1.9 \text{ kg/s}$
 $P_3 = 50 \text{ kPa}$
 $T_3 = 100^\circ\text{C}$

Find: Determine the power produced by this turbine in kW.

Schematic:



10/10

Find Analysis:

At $P(500 \text{ kPa})$ and $T(100^\circ\text{C})$, enthalpy $h_3 = 2682.4 \text{ kJ/kg}$

$$s_1 = s_2 = s_3 = 7.6953 \text{ kJ/kg}\cdot\text{K}$$

$$\frac{400 - T_2}{400 - 350} = \frac{7.7956 - 7.6953}{7.7956 - 7.6396} \Rightarrow T_2 = 368.85^\circ\text{C}$$

h_2 at 368.85°C and 500 kPa :

$$\frac{3272.4 - h_2}{3272.4 - 3168.1} = \frac{400 - 368.85}{400 - 350} \Rightarrow h_2 = 3207.42 \text{ kJ/kg}$$

$T_1 =$

$$\frac{700 - T_1}{700 - 600} = \frac{7.759 - 7.6953}{7.759 - 7.5103}$$

$$T_1 = 674.4^\circ\text{C}$$

$$\frac{3912.2 - h_1}{3912.2 - 3682.8} = \frac{700 - 674.4}{700 - 600}$$

$$h_1 = 3853.47 \text{ kJ/kg}$$

$$\text{Power, } W = (m_1 h_1 - m_2 h_2 - m_3 h_3)$$

$$= [(2 \times 3853.47) - (0.1 \times 3207.42) - (1.9 \times 2682.4)]$$

$$= [7706.94 - 320.742 - 5096.56]$$

$$W = 2289.64 \text{ kW}$$

Comment: use properties of Super heated water.

7.60

Given: $T_1 = 120^\circ\text{C} = 393\text{K}$

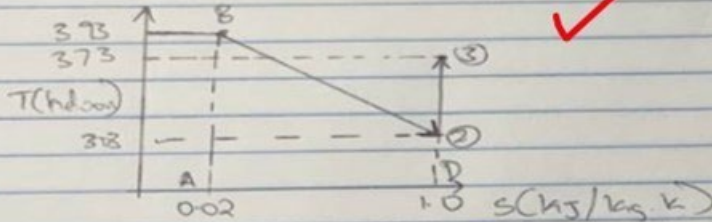
$T_2 = 30^\circ\text{C} = 303\text{K}$

$T_3 = 100^\circ\text{C} = 373\text{K}$

10/10

Find: Calculate the heat transfer, in kJ/kg

Schematic:



Analysis: Area 1 to 2 + Area 2 to 3

Area of trapezium ABCD is

$$= \frac{1}{2} \times (AB + CD) \times AD$$

$$= \frac{1}{2} (393 + 303) \times (1.0 - 0.02)$$

$$= \frac{1}{2} \times 696 \times 0.98 = 341.04\text{kJ}$$

So, the total heat transfer for process 1 to 3 is 341.04 kJ.

Comment: Area 2 to 3 is zero; Area of trapezium $= \frac{1}{2} \times \text{Sum of parallel} \times \text{distance between them}$

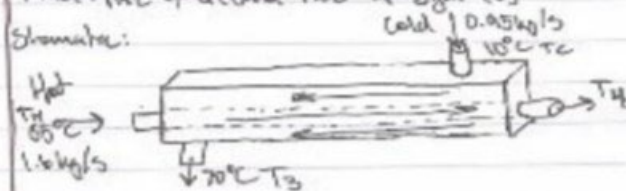
Group 2

7-141

Given: $c_p^{\text{hot}} = 4.18 \text{ kJ/kg} \cdot ^\circ\text{C}$ $T_{\text{in,c}} = 10^\circ\text{C}$ $T_{\text{in,h}} = 85^\circ\text{C}$ $T_{\text{out}} = 70^\circ\text{C}$
 $c_p^{\text{cold}} = 4.19 \text{ kJ/kg} \cdot ^\circ\text{C}$ $\dot{m}_c = 0.95 \text{ kg/s}$ $\dot{m}_h = 1.6 \text{ kg/s}$

Find: Rate of Q (and rate of S_{gen})

Schematic:



9/19

Assumption: Well-insulated and steady system

Analysis:

$$a) E_{\text{in}} - E_{\text{out}} = \Delta E_{\text{sys}}$$

$$\Rightarrow \dot{m}_h c_p T_H + \dot{m}_c c_p T_C - \dot{m}_h c_p T_H - \dot{m}_c c_p T_C = 0$$

$$\Rightarrow 1.6(4.19)(85) + 0.95(4.19)(10) - 1.6(4.19)T_H - 0.95(4.19)(70) = 0$$

$$\Rightarrow T_H = 49.46^\circ\text{C}$$

$$\dot{Q} = \dot{m}_c c_p (T_C - T_H) \Rightarrow 0.95(4.19)(70 - 10)$$

$$\Rightarrow \dot{Q} = 238.26 \text{ kW}$$

$$b) \dot{S}_{\text{gen}} = \dot{m}_c c_p \ln \left[\frac{T_C}{T_H} \right] + \dot{m}_h c_p \ln \left[\frac{T_H}{T_C} \right] \quad \text{a temp convert to K}$$

$$\Rightarrow \dot{S}_{\text{gen}} = 0.95(4.19) \ln \left[\frac{345}{285} \right] + 1.6(4.19) \ln \left[\frac{322.46}{358} \right]$$

$$\Rightarrow \dot{S}_{\text{gen}} = 0.0626 \text{ kW/K}$$

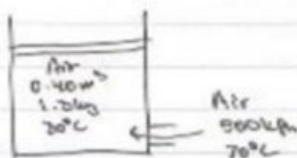
Comments: Use energy balance then entropy balance

Group 2

7-216

Given: $V = 0.40 \text{ m}^3$ Air in: 900 kPa 70°C Air: 1.2 kg 30°C Find: (a) W , (b) T_2 , (c) m_2 , (d) $\dot{S}_{\text{gen}}$

Schematic:

Assumptions: Air is a ~~uniform~~ ^{+50%} ideal gas w/ constant specific heatsAnalysis: $\frac{V_1}{2} = .2 \text{ m}^3$ ~~where~~ $V_2 = .2 = V_1 = .60 \text{ m}^3$ $P_1 V_1 = m R T_1$ $^\circ\text{C} \rightarrow \text{K}$

a) $W = P_1 (V_2 - V_1) = 282.62 (0.6 - 0.4)$

$$W = 56.52 \text{ kJ}$$

$$= 1.3 \times 0.287 \times 303$$

$$\frac{0.4}{0.8}$$

$$P_1 = 282.62 \text{ kPa}$$

$$E_{\text{in}} - E_{\text{out}} = \Delta E_{\text{sys}}$$

b) $(m_2 u_2 - m_1 u_1) = \dot{Q}_{\text{in}} - W_{\text{out}} \quad u = C_v T \quad u_2 = C_v T_2$

$$(m_2 C_v T_2 - m_1 C_v T_1) = (m_2 - m_1) C_v T_1 - W_{\text{out}}$$

$$C_v \left(\frac{P_2 V_2}{P_1} - \frac{P_1 V_1}{P_1} \right) = (m_2 - 1.3) \times 1.4 \times (273 + 70) - 56.52$$

$$\frac{0.717}{0.287} (0.6 - 0.4) \times 282.62 = (m_2 - 1.3) \times 344.78 - 56.52$$

$$m_2 = 1.8736 \text{ kg}$$

$$P_2 V_2 = m_2 R T_2$$

$$T_2 = \frac{282.62 \times 0.6}{1.8736 \times 0.287}$$

$$T_2 = 315.34 \text{ K}$$

c) $m_2 - m_1 = m = 1.8736 - 1.3 = 0.5736 \text{ kg} = m_1$

$$P_2 = P_1$$

d) $\dot{S}_{\text{gen}} = \left(m_2 c_p \ln \left(\frac{T_2}{T_1} \right) - m R \ln \left(\frac{P_2}{P_1} \right) \right) + \left(m_1 c_p \ln \left(\frac{T_2}{T_1} \right) - m_1 R \ln \left(\frac{P_2}{P_1} \right) \right)$

$$\dot{S}_{\text{gen}} = 1.3 \times 1.005 \ln \left(\frac{315.34}{303} \right) + 0.5736 \times 1.005 \ln \left(\frac{315.34}{303} \right) - 0.5736 \times 0.287 \ln \left(\frac{282.62}{900} \right)$$

$$\dot{S}_{\text{gen}} = 0.09736 \text{ kJ/K}$$

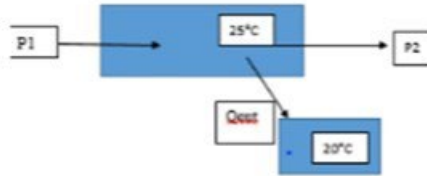
Comments: none

BELOW AVERAGE

7-24

Problem Statement: Air is compressed by a 40-kW compressor from P_1 to P_2 . The air temperature is maintained constant at 25°C during this process as a result of heat transfer to the surrounding medium at 20°C . Determine the rate of entropy change of the air. State the assumptions made in solving this problem.

Schematic:



10/10

Analysis:

Given: $\dot{W} = 40 \text{ kW}$
 $T_{\text{sys}} = T_{\text{air}} = 25^\circ\text{C}$ (T_{air} is constant)
 $T_{\text{sur}} = 20^\circ\text{C}$

Find: $\Delta \dot{S}_{\text{sys}}$

Assumptions:

- 1) steady-flow process
- 2) ΔKE , ΔPE are negligible
- 3) air is an ideal gas
- 4) Isothermal, internally reversible process



$$\dot{E}_{\text{in}} - \dot{E}_{\text{out}} = \Delta \dot{E}_{\text{system}} = 0$$

$$\dot{E}_{\text{in}} = \dot{E}_{\text{out}}$$

$$\dot{m}h_1 + \dot{W} = \dot{m}h_2 + \dot{Q}$$

$$\dot{m}(h_1 - h_2) + \dot{W} = \dot{Q}$$

$$\rightarrow [\text{Ideal gas: } h = h(T) \Rightarrow h_1 = h_2 \text{ since } T_1 = T_2]$$

$$\dot{Q} = \dot{W} = 40 \text{ kW}$$

$$\Delta \dot{S}_{\text{sys}} = -\frac{\dot{Q}_{\text{out, air}}}{T_{\text{sys}}} = -\frac{40 \text{ kW}}{298 \text{ K}}$$

$$\Delta \dot{S}_{\text{sys}} = -0.134 \text{ kW/K}$$



Comments: The change in enthalpy of the system was negative because the system released heat to the surroundings.

7-30E

Problem Statement: Calculate the heat transfer, in kJ/kg, for the reversible steady-flow process 1-3 shown on a T-s diagram in Fig. P7-60. 10/10

Known: $P_1 = 100$ psia, $T_1 = 100$ °F, $P_2 = 10$ psia, weight = 1 lbm

Find: Total heat transfer and work production for this process.

Schematic: None

Assumptions: the system is isentropic and reversible so there is no heat transfer.

Properties: all properties are known

Analysis: Energy balance formula

$$E(\text{in}) - E(\text{out}) = E_2 - E_1$$

$$W(\text{out}) = m(u_1 - u_2)$$

$$U_1 = 109.46 \text{ Btu/lbm} \quad s_1 = .22902 \text{ Btu/lbm} \cdot \text{R} \quad s_2 = s_1 \quad P_2 = 10 \text{ psia}$$

Solve for x_2

$$X_2 = (s - s_f) / s_{fg} = (.22902 - .00741) / .22208 = .9979$$

Solve for u_2

$$u_2 = u_f + x_2 u_{fg} = 3.132 \text{ ft}^3/\text{lbm} + (.9979 * 87.463 \text{ Btu/lbm}) = 90.4 \text{ Btu/lbm}$$

Plug in the u_2 value for work

$$W(\text{out}) = 1 \text{ lbm}(109.46 - 90.4) \text{ Btu/lbm} = 19.06 \text{ Btu}$$

7-36

Problem Statement: An insulated piston-cylinder device contains 0.05 m³ of saturated refrigerant-134a vapor at 0.8-MPa pressure. The refrigerant is now allowed to expand in a reversible manner until the pressure drops to 0.4 MPa.

Known: P₁ = 0.8 MPa, P₂ = 0.4 MPa, V = 0.05 m³

Find: The final temperature and work done.

Schematic:

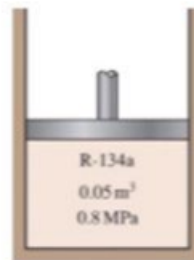


FIGURE P7-36

10/10

Assumptions: The process is reversible adiabatic process, so $s_2 = s_1$. In order to find the work we need. Also in order to find mass we need to use the specific volume (v_1).

Properties: $s_2 = s_1$, and it is a saturated vapor.

Analysis: solve for x_2 and then use the saturated mixture to find u_2 and T_2 .

A. State 1: P₁ = 0.8 MPa, $v_1 = 0.025645 \text{ m}^3/\text{kg}$, $u_1 = 246.82 \text{ kJ/kg}$, $s_1 = 0.91853 \text{ kJ/kg}\cdot\text{K}$

$$x_2 = \frac{(s_1 - s_{f2})}{s_{fg2}} = \frac{(0.91853 - 0.24757)}{0.67954} \text{ (kJ/kg}\cdot\text{K)} = 0.98737$$

$$u_2 = u_{f2} + x_2 \cdot u_{fg2} = 63.92 \text{ kJ/kg} + (0.98737)(171.49) \text{ kJ/kg} = 233.24 \text{ kJ/kg}$$

$$T_2 = 8.91 \text{ }^\circ\text{C}$$

• State 2: P₂ = 0.4 MPa, $s_2 = s_1$, $u_2 = 233.24 \text{ kJ/kg}$, $T_2 = 8.91 \text{ }^\circ\text{C}$

B. To find work, use energy balance formula to find m and then solve for work

$$\bullet \text{ Mass}(m) = V/v_1 = 0.05 \text{ m}^3 / 0.025645 \text{ m}^3/\text{kg} = 1.95 \text{ kg}$$

$$\bullet E_{\text{in}} - E_{\text{out}} = E_2 - E_1 \Rightarrow -W(b) = m(u_2 - u_1) \Rightarrow -W(b) = (1.95 \text{ kg})(233.24 - 246.82) \text{ kJ/kg}$$

$$-W(b) = -27.5674 \text{ kJ} \Rightarrow W(b) = 27.5674 \text{ kJ}$$

7-51

Problem Statement: An isentropic steam turbine processes 2 kg/s of steam at 3 MPa, which is exhausted at 50 kPa and 100°C. Five per-cent of this flow is diverted for feedwater heating at 500 kPa.

2/10

Known: $\dot{m}_1 = 2 \text{ kg/s}$, $P_1 = 3 \text{ MPa}$, $P_3 = 50 \text{ kPa}$, $T_3 = 100^\circ\text{C} = 373.15 \text{ K}$, $P_2 = 500 \text{ kPa}$

Find: the power produce within the turbine

Schematic:

Properties: $\dot{m}_2$ is 5% of $\dot{m}_1$ so, $\dot{m}_2 = 1 - (2 \times .05) = \cancel{9} \text{ kg/s}$

$2 - 2(.05) =$

Assumptions: entropy is constant so $s_1 = s_3$

Analysis: solve for $\dot{m}_3$

$\dot{m}_3 = \dot{m}_1 - \dot{m}_2 = (2 - .9) \text{ kg/s} = 1.1 \text{ kg/s}$

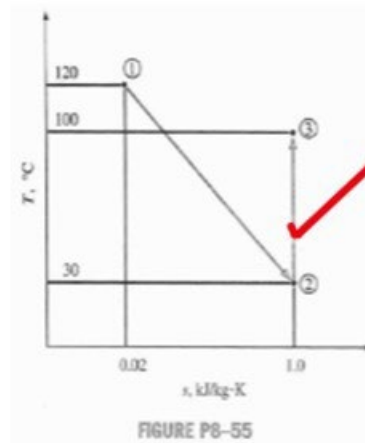
Problem Statement: Calculate the heat transfer, in kJ/kg, for the reversible steady-flow process 1-3 shown on a T-s diagram in Fig. P7-60.

Known: $T_1 = 120^\circ\text{C} = 393\text{ K}$, $T_2 = 30^\circ\text{C} = 303\text{ K}$, $T_3 = 100^\circ\text{C} = 373\text{ K}$, $1/2 \times \text{sum of the sides parallel} \times \text{distance between them}$

Find: Heat transfer for reversible steady-flow process

Schematic:

10/10



Properties: All Properties are known

Analysis: Area under T-S curve $\times$ Area under process 1.) to 2.) $\times$ Area under 2.) to 3.) =

Area of trapezoid ABCD

$(1/2)(AB+CD) \times AD$

Solution Plan: Complete the area to find heat transfer using equation from analysis

$$Q(1-3) = (1/2)(393+303)(1.0-0.02)$$

$$Q(H) = (1/2)(696)(.98)$$

$$Q(H) = 341.04 \text{ kJ}$$

7-141

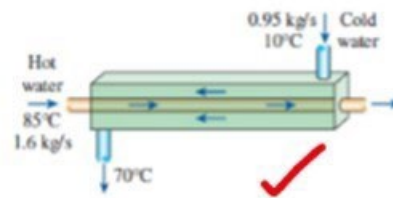
Problem Statement: Cold water ($c_p = 4.18 \text{ kJ/kg} \cdot ^\circ\text{C}$) leading to a shower enters a well-insulated, thin-walled, double-pipe, counterflow heat exchanger at 10°C at a rate of 0.95 kg/s and is heated to 70°C by hot water ($c_p = 4.19 \text{ kJ/kg} \cdot ^\circ\text{C}$) that enters at 85°C at a rate of 1.6 kg/s . Determine (a) the rate of heat transfer and (b) the rate of entropy generation in the heat exchanger.

Known: $C_p \text{ cold} = 4.18 \text{ kJ/kg} \cdot ^\circ\text{C}$, $C_p \text{ hot} = 4.19 \text{ kJ/kg} \cdot ^\circ\text{C}$

Find: (a) rate of heat transfer, (b) the rate of entropy generation in the heat exchanger

Assumptions: Steady-flow, kinetic and potential energies are negligible

Schematic:



9/10

Analysis:

$$\begin{aligned} \text{(a) } \dot{Q} &= \dot{m} c_p \Delta T \\ &\Downarrow \text{consider the cold water} \\ \dot{Q} &= \dot{m}_c c_{p, \text{cold}} (T_{2, c} - T_{1, c}) \\ \dot{Q} &= (0.95 \frac{\text{kg}}{\text{s}}) (4.18 \frac{\text{kJ}}{\text{kg} \cdot ^\circ\text{C}}) (70^\circ\text{C} - 10^\circ\text{C}) \\ \dot{Q} &= 238.26 \text{ kW} \end{aligned}$$

$$\begin{aligned} \text{(b) } \dot{S}_{\text{gen}} &= \Delta S_{\text{cold}} + \Delta S_{\text{hot}} \\ \dot{S}_{\text{gen}} &= \dot{m}_c c_{p, c} \ln \frac{T_{2, c}}{T_{1, c}} + \dot{m}_h c_{p, h} \ln \frac{T_{2, h}}{T_{1, h}} \\ &\rightarrow \left[\begin{array}{l} \text{Hot water outlet temp } (T_{2, h}) \text{ is unknown:} \\ \dot{Q}_{\text{cold}} = \dot{Q}_{\text{hot}} \\ \dot{Q}_{\text{cold}} = \dot{m}_h c_{p, \text{hot}} (T_{1, h} - T_{2, h}) \\ T_{2, h} = \frac{-\dot{Q}}{\dot{m}_h c_{p, \text{hot}}} + T_{1, h} = 49.5^\circ\text{C} \end{array} \right] \\ \dot{S}_{\text{gen}} &= 0.0634 \frac{\text{kJ}}{\text{K}} \end{aligned}$$

Comments: The entropy generated is generated by the heat transfer between the two pipes.

7-216

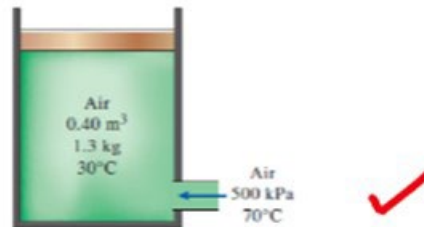
Problem Statement: A 0.40-m³ insulated piston-cylinder device initially contains 1.3 kg of air at 30°C. At this state, the piston is free to move. Now air at 500 kPa and 70°C is allowed to enter the cylinder from a supply line until the volume increases by 50 percent.

Known: $V_1 = .4 \text{ m}^3$, $m_1 = 1.3 \text{ kg}$, $T_1 = 30^\circ\text{C}$, $P_i = 500 \text{ kPa}$, $T_i = 70^\circ\text{C}$,

$$V_2 = ((.5).4 + .4) \text{ m}^3 = .6 \text{ m}^3$$

Find: A.) T_2 , B.) m_i , C.) Work, and D.) $S(\text{gen})$

Schematic:



9/10

Assumptions: The system is isolated so $(\Delta)Q=0$, and the pressure remains constant as well as the entropy.

Properties: $R = .287 \text{ kJ/kg}\cdot\text{K}$

Analysis: To find T_2 we need to find P_2 and m_2

A. $PV_1 = mRT_1 \Rightarrow P = ((m_1RT_1)/V_1) \Rightarrow ((1.3 \text{ kg})(.287 \text{ kJ/kg}\cdot\text{K})(303.15 \text{ K}))/.4 \text{ m}^3 = 282.8 \text{ kPa}$

• $m_2 = (PV_2)/RT_2 = (282.8 \text{ kPa} \cdot .6 \text{ m}^3)/(.287 \text{ kJ/kg}\cdot\text{K} \times T_2) = 591.22/T_2$

$m_2 = 1.88 \text{ kg}$

• Use the energy balance formula to solve for T_2 by plugging in the value for $m(i)$.

$E(\text{in}) - E(\text{out}) = E_2 - E_1 \Rightarrow m(i)h(i) - W = m_2u_2 - m_1u_1 \Rightarrow (m_2 - m_1)h(i) - W = m_2u_2 - m_1u_1$

$\Rightarrow ((P_2V_2)/RT_2 - m_1)C_pT_i - W = (P_2V_2)/RT_2 C_vT_2 - m_1C_vT_1$

$\Rightarrow ((591.22/T_2) - 1.3 \text{ kg})(1.005 \text{ kJ/kg}\cdot\text{K})(343.15 \text{ K}) - 56.56 \text{ kJ} =$

$(591.22/T_2)(.718 \text{ kJ/kg}\cdot\text{K})T_2 - (1.3 \text{ kg})(1.005 \text{ kJ/kg}\cdot\text{K})(303.15 \text{ K})$

$T_2 = 315 \text{ K}$

B. Use the energy balance system twice to find $m(i)$

• $m_2 - m_1 = m(i) - m(e) \Rightarrow (591.22/T_2) \text{ kg} - 1.3 \text{ kg} = m(i) - 0 \Rightarrow$

$m(i) = (591.22/T_2) \text{ kg} - 1.3 \text{ kg}$

$$m(i) = .6 \text{ kg}$$

$$C. W = P(V_2 - V_1) \Rightarrow W = 282.8 \text{ kPa}(.6-.4)m^3 \Rightarrow W = 56.56 \text{ kJ}$$

D. $S(\text{gen})$:

$$m(i)S(i) + S(\text{gen}) = m_2S_2 - m_1S_1 \quad , \quad (\Delta Q) = 0$$

$$(m_2 - m_1)S(i) + S(\text{gen}) = m_2S_2 - m_1S_1$$

$$S(\text{gen}) = m_2(S_2 - S(i)) - m_1(S_1 - S(i))$$

$$S(\text{gen}) = m_2C_p[\ln(T_2/T_i) - R \ln(P_2/P_i)] - m_1C_p[\ln(T_1/T_i) - R \ln(P_1/P_i)]$$

$$S(\text{gen}) = (1.8 \text{ kg})(1.005 \text{ kJ/kg} \cdot \text{K})[\ln((315/343.15)\text{K}) - \ln(.287(282.8/500)\text{kPa})] -$$

$$1.3 \text{ kg}(1.005 \text{ kJ/kg} \cdot \text{K})[\ln((303.15/343.15)\text{K}) - \ln(287(\text{kJ/kg} \cdot \text{K})((282.8/500)\text{kPa}))]$$

$$S(\text{gen}) = .81 \text{ kJ}$$

