

**PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF CHEMICAL ENGINEERING
CHEG 2334- Chemical Engineering Thermodynamics I
FALL 2021**

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 - Average (Graded original work)**
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 - 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]

Course Description in ABET Format

CHEMICAL ENGINEERING DEPARTMENT CHEG 2334 Course Syllabus

1. **Course number and name:** CHEG 2334 CHEMICAL ENGINEERING THERMODYNAMICS I
2. **Credits and contact hours:** 3 credit hours; 6 contact hours
3. **Instructor's or course coordinator's name:** Dr. Kazeem Olanrewaju
4. **Text book: Title:** INTRODUCTION TO CHEMICAL THERMODYNAMICS

Author: Smith, J. M, Van Ness, H. C., Abbott, M. M., and Swihart, M. T.
Publisher, Year & Edition: McGraw Hill Education, New York, 2017, 8th Edition
 - a. Other Supplemental material
 1. Perry's Chemical Engineers' Handbook, Edition 8, by Don Green, Robert Perry, Robert H. Perry Introduction to Chemical Engineering Thermodynamics. ISBN13: 978-0-07-142294-9
 2. Fundamentals of Engineering Thermodynamics, 8th edition, M.J Moran, H. N. Shapiro, D. D. Boettner, M. B. Bailey, Wiley, 2014 ISBN : 978-1-118-41293-0 (US)
5. **Specific course information**
 - a. Brief description of the content of the course (catalog description) CHEG 2334. Chemical Engineering Thermodynamics I. (3-0) Credit 3 semester hours. Introduction to Chemical Engineering Calculations. PVT Properties of Fluids. Equations of State. First and Second Law of Thermodynamics. Applications to Heat Effects and Flow Processes.
 - b. Prerequisites or Co-requisites CHEM 1403 (or 1304) and PHYS 2325
 - 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 This course prepares engineering students	b. Explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are
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with the following outcomes.

addressed by the course.

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. Define the concept of energy and entropy. Identify work and heat as the two forms of energy transfer. Describe the first and second law of thermodynamics with applications to real processes and cycles.

2. Explain carnot theorem derivation and efficiency concept. Discuss equations of state of pure substances such as van der Waals, general cubic, and Virial E.O.S.

3. Describe and discuss in detail the applications of efficiency and laws of thermodynamics to turbines, pumps, refrigerators, automobiles and combined cycle power plants.

4. Describe sensible heat as heat transfer to a system in which there no phase changes, no chemical reactions, and no composition except temparture change in the temperature of the system. Use Gibbs Phase Rule to fix intensive properties of a close system.

Outcome D1**

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

7 Brief list of topics to be covered

Introduction	(3 hours)
The First Law and other Basic Concepts	(10 hours)
Volumetric Properties of Pure Fluids	(12 hours)
Heat Effects	(5 hours)
The Second Law of Thermodynamics	(5 hours)

***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

II ASSESSMENT RESULTS FOR CURRENT AND PAST THREE PERIODS

Program Outcomes Assessed in this course

Outcome D1:

An ability to identify, formulate, and solve fundamental engineering problems (CEP) by applying principles of engineering, science, and mathematics.

Assessment Summary of Class Semester Averages for Outcomes (Should be provided for Spring 2018 through Fall 2021 Assessment Period)

Outcomes	D1
Semester	Semester Class Average (%)
Spring 2018	76.75
Fall 2020	73.78
Fall 2021	56.5
Comments on Trend of Data (Improving or deteriorating)	The outcome for the current semesters show that students' performance significantly fall below the expected class average and also, the % of students meeting expected average is observed to be lower than the expected average. The last two years show a better performance both on the class average and percentage of students meeting 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.

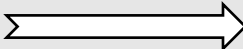
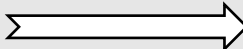
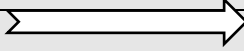
5. Were Expectations Met?

- 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**.

END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
CHEG 2334-P01: CHEMICAL ENGINEERING THERMODYNAMICS I
FALL 2021 SEMESTER

Report Prepared by: Dr. Kazeem Olanrewaju

Report Date: December 19, 2021

Semester	Analysis Type	Number of Students	Outcome 1 An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.”			
			Expected Class Average	Expected Percent of students at or above average	Class Average	% Students meeting Expected Average
Spring 2019	Direct	10	75	70	76.75	60.50
Fall 2020	Direct	18	75	70	73.78	61.11
Fall 2021	Direct	12	75	70	56.5	41.67
Implementation Summary			Sufficient time was spent explaining the relevant and the physical meaning of common thermodynamics parameter and the differentiation equation (accumulation terms) and other terms describing the flow process in an open system. Instructor spent time explaining how objective function is use to solve problem that requires iteration both analytically and computationally.			
Perceived Problems			Students show little or no interest in coming to class due to the discouraging influence of over a year-long online class necessitated by COVID-19. Students don't spend much time solving homework problems and as result they find it difficult to do well in test, quiz, and exam.			
Plans for Addressing Problems			The following is recommended for implementation: 1. Face-to-face class should be significantly incentivized by attaching one-tenth of the total percentage point to attendance 2. Instructor should encourage students to do their homework by testing their understanding on some of the equation given to them in homework during test, quiz, and exam			
Overall Trend over Periods			The outcome for the current semesters depict student performance falls below the expected class average and also, the % of students meeting expected average is observed to be lower than the expected average. The last two years show a better performance both on the class average and percentage of students meeting expected average			
Were Expectations Met?	Class Average $\geq 75\%$ and $\geq 70\%$ of Students Performed at or Above Expected Average.		No			

**CHEMICAL ENGINEERING THERMODYNAMICS I
FALL 2021**

Title of Assignment: TEST 1

TOPICS COVERED IN TEST 1

Test 1 covered the following topics:

1. Dimensions and Units
2. Force
3. Work, Energy, Heat
4. First Law of Thermodynamics
5. Energy Balance for Closed Systems

CHEMICAL ENGINEERING THERMODYNAMICS I
FALL 2021

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

Prairie View A & M University, CHEG 2334: Thermodynamics I; Fall 2021: Test 1,
Wednesday, September 22, 2021, Instructor: Dr. Kazeem Olanrewaju
Part 2: Open Book (only hard copy of the Textbook)

Name of Student: _____

Problem 1 (80 points)

Neon gas contained in a vertical piston–cylinder assembly on which rests a weight. The mass of weight and the piston are respectively 70lbm and 200lbm. The piston-cylinder's diameter is 1.45 ft. The local acceleration due to gravity is 32.170 ft/s^2 and the atmospheric pressure is 14.7psi. Electric current passes through the heating element, and the volume of the neon gas slowly increases by 0.071 m^3 while its pressure remains constant. The mass of the neon gas is 0.45 lbm, and its specific internal energy increases by 25 Btu/lbm. The neon gas and piston are at rest initially and finally. The piston–cylinder material is a ceramic composite and thus a good insulator. Friction between the piston and cylinder wall can be ignored, and the local acceleration of gravity is $g = 32.0 \text{ ft/s}^2$. Neon gas is consider to be the system.

- a) Determine the work done by the neon gas in BTU ?
 - b) Determine the heat transfer from the heating element to the neon gas, in $\text{lb}_f\text{-ft}$.
 - c) Estimate the value of an external force F in N applied to the system to recover 30% of the heat input in (b) of which part of it was lost to work. This external force F reduces the final volume of the gas in (b) by 1.5 ft^3 .
- .

(1)

THERMODYNAMICS I TEST 1, PART 2, FALL 2021 SOLUTIONS

Problem 1

Given:

Mass of object weight, $M_w = 70 \text{ lbm}$

Mass of piston, $M_p = 200 \text{ lbm}$

Diameter of Piston-cylinder, $D = 1.45 \text{ ft}$

Local acceleration due to gravity, $g = 32.170 \text{ ft/s}^2$

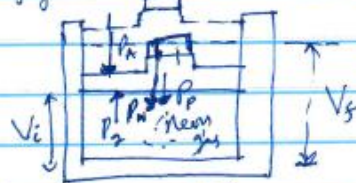
Atmospheric pressure, $P_a = 14.7 \text{ psi}$

Increases in volume, $\Delta V = 0.071 \text{ m}^3$

Mass of neon gas, $M_g = 0.45 \text{ lbm}$

Specific Internal Energy increment = $25 \text{ Btu/lbm} = \Delta \hat{U}$

~~for~~



Formulate

$$F = W = \frac{1}{g_c} \vec{m} \cdot \vec{g}, \quad P = \frac{F}{A}; \quad W_{\text{net}} = -F \Delta h = -P \Delta V$$

$$\Delta U = Q + W_{\text{net}}; \quad g_c = \frac{32.17 \text{ ft} \cdot \text{lbm} / \text{s}^2}{1 \text{ lbf}}; \quad \sum \vec{F}_i = 0$$

$$\Delta U = Q + W$$

$$P_g = P_a + P_p + P_w$$

Solve

(a) To determine the work done by the neon gas in Btu

$$W = -P \Delta V$$

(2)

$$P_g = P_A + P_w + P_p$$

$$P_A = 14.7 \text{ psi}$$

$$\therefore P_w = \frac{F_w}{A}; \text{ But } F_w = \frac{1}{g_c} M_w g$$

$$\therefore F_w = \frac{1 \text{ lb}_f}{32.174 \frac{\text{lbm} \cdot \text{ft}}{\text{s}^2}} \times 70 \text{ lbm} \times 32.170 \frac{\text{ft}}{\text{s}^2}$$

$$F_w = 69.99 \text{ lb}_f$$

$$\therefore A = \frac{\pi D^2}{4} = \frac{3.142 \times 1.45^2 \text{ ft}^2}{4} = 1.652 \text{ ft}^2$$

$$A = \frac{1.652 \text{ ft}^2}{1 \text{ ft}^2} \times \frac{144 \text{ in}^2}{1 \text{ ft}^2} = 237.89 \text{ in}^2$$

$$\therefore P_w = \frac{69.99 \text{ lb}_f}{237.89 \text{ in}^2} = 0.294 \text{ lb}_f/\text{in}^2$$

$$P_p = \frac{F_p}{A}, \text{ But } F_p = \frac{1}{g_c} M_p g$$

$$\therefore F_p = \frac{1 \text{ lb}_f}{32.174 \frac{\text{lbm} \cdot \text{ft}}{\text{s}^2}} \times 200 \text{ lbm} \times 32.170 \frac{\text{ft}}{\text{s}^2}$$

$$F_p = 199.98 \text{ lb}_f$$

(3)

$$P_p = \frac{F_p}{A} = \frac{199.98 \text{ lb}}{237.89 \text{ in}^2} = 0.841 \text{ lb/in}^2$$

$$\therefore P_g = P_a + P_m + P_p$$

$$P_g = 14.7 \text{ psi} + 0.294 \text{ psi} + 0.841 \text{ psi}$$

$$P_g = 15.835 \text{ psi}$$

$$\therefore P_g = 15.835 \frac{\text{lb}}{\text{in}^2} \times \frac{144 \text{ in}^2}{1 \text{ ft}^2}$$

$$P_g = 2280.24 \frac{\text{lb}}{\text{ft}^2}$$

(10)

$$\therefore W = -P \Delta V$$

$$= -2280.24 \frac{\text{lb}}{\text{ft}^2} \times 0.071 \text{ ft}^3 \left| \frac{35.315 \text{ ft}^3}{1 \text{ m}^3} \right.$$

$$\therefore W = -5717.39 \text{ lb} \cdot \text{ft} \left\{ \begin{array}{l} 1 \text{ Btu} \\ 778.169 \text{ lb} \cdot \text{ft} \end{array} \right.$$

$$W = -7.35 \text{ Btu} \quad (5)$$

(4)

(b) To determine the heat transfer from the heating element to the neon gas, in kJ-R

$$\therefore \Delta U = Q + W$$

$$\therefore Q = \Delta U - W$$

$$\therefore \hat{\Delta U} = 25 \text{ kJ/kg}$$

(10)

$$\begin{aligned} \therefore \Delta U &= \hat{\Delta U} \times \text{Mass of gas} \\ &= \frac{25 \text{ kJ}}{\text{kg}} \times 0.465 \text{ kg} \end{aligned}$$

$$\therefore \Delta U = 11.625 \text{ kJ}$$

$$Q = 11.625 \text{ kJ} - (-7.35 \text{ kJ})$$

$$Q = 18.975 \text{ kJ}$$

(5)

(c) To estimate the value of an external force F applied to the system to recover 30%

$$\frac{\text{30\% of heat input}}{\text{lost to work}} = \frac{30}{100} \times \frac{18.975 \text{ kJ}}{1}$$

$$= \frac{5.6925 \text{ kJ}}{1 \text{ kJ}} \times \frac{773.169 \text{ kJ-R}}{1 \text{ kJ}} =$$

$$= 4392.18 \text{ kJ-R}$$

(5)

$$W = -P\Delta V = -F\Delta L = 4342.18 \text{ lb}_f \cdot \text{ft}$$

$$W = -\frac{F}{A} \Delta V = 4342.18 \text{ lb}_f \cdot \text{ft}$$

(10)

$$W = -\frac{F}{1.652 \text{ ft}^2} \times 1.5 \text{ ft}^3 = 4342.18 \text{ lb}_f \cdot \text{ft}$$

$$\frac{-F}{1.652} \times 1.5 \text{ ft} = 4342.18 \text{ lb}_f \cdot \text{ft}$$

$$\therefore F = \frac{4342.18 \text{ lb}_f \times 1.652}{1.5}$$

$$F = 4782.19 \text{ lb}_f$$

(5)

IN Newton

$$F = \frac{4782.19 \text{ lb}_f}{1 \text{ lb}_f} \times 4.45 \text{ N}$$

$$F = 21280.73 \text{ N}$$

Prairie View A & M University, CHEG 2334: Chemical Engineering Thermodynamics I Fall 2021: Test 1, Wednesday, September 22, 2021. Instructor: Dr. Kazeem Olanrewaju

Closed Books

Name of Student: _____

	Terms (A)	Concept (B)	
1	System	Quantity of heat which when transferred to one pound mass of water raised its temperature one degree Fahrenheit	19
2	Specific Volume	The summation of the change in system energy and the change in the energy of the surrounding is	14
3	Potential energy	Energy added to a fluid as work is later transferred from the fluid as heat. Where is this energy between its addition to and transfer from the fluid?	20
4	Vacuum pressure	The units of force in centimeters-grams-seconds system of units is	16
5	Closed systems	Energy can neither be created nor destroyed, but rather transformed from one state to another	11
6	Kinetic energy	The real or imaginary surface that separates the system from its surroundings	18
7	Dimensions	A system where neither matter nor energy cross its boundaries is said to be	15
8	Work	Adjustable piston head of a closed system is consider :	13
9	Heat	The principle of energy conservation for all purely mechanical processes is affirm by	17
10	Temperature	There is transfer of energy across the boundary but no mass transfer	5
11	First law of thermodynamics	Energy in transition across the boundaries of a system due to a driving force other than temperature, and not associated with mass flowing across the boundary	8
12	Pressure	This is one of the energies associated with the system besides internal energy	3
13	Movable boundary	The difference between the absolute pressures of the atmosphere existing outside the measuring device and the absolute pressure of a system	4
14	Zero	A measure of the tendency of an object to spontaneously give up energy in form of heat to its surroundings is:	10
15	Isolated	$E_k = \frac{1}{2}mv^2$	6
16	Dyne	The reciprocal of the density of a liquid is	2
17	$\Delta K.E + \Delta P.E = 0$	Foot-pound force (f·lb _f) is one of the units used to describe a thermodynamics quantity and that parameter is:	9
18	Boundary	Measurable properties in thermodynamics are refer to as	7
19	BTU	A quantity of matter or a region in space chosen for study	1
20	Internal energy	This thermodynamics variable is a measure of equivalent height	12

ABOVE AVERAGE

Above Average Student Original Graded Assignment

Prairie View A & M University, CHEG 2334: Thermodynamics I; Fall 2021: Test 1,
 Wednesday, September 22, 2021, Instructor: Dr. Kazeem Olanrewaju
 Part 2: Open Book (only hard copy of the Textbook)

Name of Student: FAVOR LOUIS

Problem 1 (80 points)

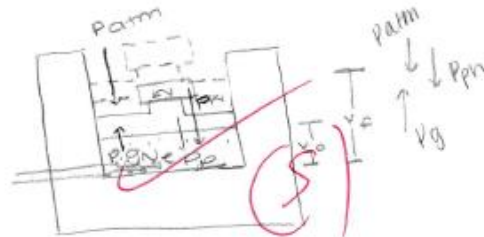
Neon gas contained in a vertical piston-cylinder assembly on which rests a weight. The mass of weight and the piston are respectively 70lbm and 200lbm. The piston-cylinder's diameter is 1.45 ft. The local acceleration due to gravity is 32.170 ft/s² and the atmospheric pressure is 14.7psi. Electric current passes through the heating element, and the volume of the neon gas slowly increases by 0.071 m³ while its pressure remains constant. The mass of the neon gas is 0.45 lbm, and its specific internal energy increases by 25 Btu/lbm. The neon gas and piston are at rest initially and finally. The piston-cylinder material is a ceramic composite and thus a good insulator. Friction between the piston and cylinder wall can be ignored, and the local acceleration of gravity is $g = 32.0 \text{ ft/s}^2$. Neon gas is considered to be the system.

- Determine the work done by the neon gas in BTU ?
- Determine the heat transfer from the heating element to the neon gas, in lbf-ft.
- Estimate the value of an external force F in N applied to the system to recover 30% of the heat input in (b) of which part of it was lost to work. This external force F reduces the final volume of the gas in (b) by 1.5 ft³.

Given

$M_w = 70 \text{ lbm}$
 $M_p = 200 \text{ lbm} > 270 \text{ lbm}$
 piston diameter = 1.45 ft
 acceleration, gravity = 32.170
 $P_{\text{atm}} = 14.7 \text{ psi}$
 $\Delta V = 0.071 \text{ m}^3$
 $M_g = 0.45 \text{ lbm}$
 $\Delta \bar{u} = 25 \text{ BTU/lbm}$

$$A = \frac{\pi d^2}{4} = \frac{\pi (1.45)^2}{4} = 1.65 \text{ ft}^2 = 237.6 \text{ in}^2$$



Formulate

$$F = W = \frac{2}{g_c} mg, P = \frac{F}{A}, W = -P \Delta V, \Delta U = \frac{\Delta \bar{u}}{\text{mass}}, \Delta U = Q + W$$

Solve

a) $w = ?$

$$P_{pw} = \frac{316 \text{ lb} (270) (32.170)}{32.174 \frac{\text{lb}}{\text{m}} \frac{\text{ft}}{\text{s}^2}} = 237.61 \text{ in}^2$$

$$P_g = P_{atm} + P_{pw} = 14.7 \text{ psi} + 2.236 \text{ psi} = 16.936 \text{ psi}$$

$$P_g = 15.836 \text{ psi} = 2280.384 \frac{\text{lb}}{\text{ft}^2} \quad \frac{25.836 \text{ lb}}{\text{ft}^2} \quad \frac{344 \text{ in}^2}{1 \text{ ft}^2}$$

$$W = -P \cdot \Delta V$$

$$= -2280.384 \times 2.505 \text{ ft}^3 = -5712.362 \text{ lb} \cdot \text{ft}$$

$$= -7.34 \text{ BTU}$$

$$\frac{0.073 \text{ m}^3 (3.28)^3 \text{ ft}^3}{1 \text{ m}^3} = 2.505 \text{ ft}^3$$

$$\frac{-5712.362 \text{ lb} \cdot \text{ft}}{778.169 \text{ lb} \cdot \text{ft} / \text{BTU}} = -7.34 \text{ BTU}$$

b) $\Delta U = \frac{\Delta U}{m}$

$$25 \text{ BTU/lbm} = \frac{\Delta U}{45} \rightarrow \Delta U = 11.25 \text{ BTU}$$

$$\Delta U = Q + W \rightarrow Q = \Delta U - W = 11.25 - (-7.34) = 18.59 \text{ BTU}$$

c) $Q = .3(18.59) = 5.57 \text{ BTU}$

$$\Delta U = Q + W \rightarrow W = \Delta U - Q$$

$$= 11.25 - 5.57 = 5.68 \text{ BTU}$$

$$P = -\frac{W}{\Delta V} = \frac{5.68}{1.5 \text{ ft}^3} = 3.79$$

you need to convert
BTU to lb_f·ft

$$P = 3.79 \text{ lb}_f / \text{ft}^2$$

$$P = \frac{F}{A} \rightarrow 3.79 = \frac{F}{2.65 \text{ ft}^2} \rightarrow F = 3.79 \times 2.65$$

$$F = 10.03 \text{ lb}_f$$

Prairie View A & M University, CHEG 2334: Chemical Engineering Thermodynamics I Fall 2021: Test 1, Wednesday, September 22, 2021. Instructor: Dr. Kazeem Olanrewaju

Closed Books

Name of Student: FCNOY LOUIS

	Terms (A)	Concept (B)
1	System	Quantity of heat which when transferred to one pound mass of water raised its temperature one degree Fahrenheit 19 ✓
2	Specific Volume	The summation of the change in system energy and the change in the energy of the surrounding is 14 ✓
3	Potential energy	Energy added to a fluid as work is later transferred from the fluid as heat. Where is this energy between its addition to and transfer from the fluid? 20 ✓
4	Vacuum pressure	The units of force in centimeters-grams-seconds system of units is 16 ✓
5	Closed systems	Energy can neither be created nor destroyed, but rather transformed from one state to another 22 ✓
6	Kinetic energy	The real or imaginary surface that separates the system from its surroundings 18 ✓
7	Dimensions	A system where neither matter nor energy cross its boundaries is said to be 15 ✓
8	Work	Adjustable piston head of a closed system is consider : 23 ✓
9	Heat	The principle of energy conservation for all purely mechanical processes is affirm by 17 ✓
10	Temperature	There is transfer of energy across the boundary but no mass transfer 5 ✓
11	First law of thermodynamics	Energy in transition across the boundaries of a system due to a driving force other than temperature, and not associated with mass flowing across the boundary 8 ✓
12	Pressure	This is one of the energies associated with the system besides internal energy 3 ✓
13	Movable boundary	The difference between the absolute pressures of the atmosphere existing outside the measuring device and the absolute pressure of a system 4 ✓
14	Zero	A measure of the tendency of an object to spontaneously give up energy in form of heat to its surroundings is: 10 ✓
15	Isolated	$E_k = \frac{1}{2}mv^2$ 6 ✓
16	Dyne	The reciprocal of the density of a liquid is 2 ✓
17	$\Delta K.E + \Delta P.E = 0$	Foot-pound force (f·lbf) is one of the units used to describe a thermodynamics quantity and that parameter is: 9 ✓
18	Boundary	Measurable properties in thermodynamics are refer to as 7 ✓
19	BTU	A quantity of matter or a region in space chosen for study 1 ✓
20	Internal energy	This thermodynamics variable is a measure of equivalent height 12 ✓

$$p = \frac{F}{A} = \frac{100}{2} = 50$$

AVERAGE

Average Student Original Graded Assignment

Prairie View A & M University, CHEG 2334: Thermodynamics I; Fall 2021: Test 1,
Wednesday, September 22, 2021, Instructor: Dr. Kazeem Olanrewaju
Part 2: Open Book (only hard copy of the Textbook)

Name of Student: Boel Wright

46
80

Problem 1 (80 points)

Neon gas contained in a vertical piston-cylinder assembly on which rests a weight. The mass of weight and the piston are respectively 70lbm and 200lbm. The piston-cylinder's diameter is 1.45 ft. The local acceleration due to gravity is 32.170 ft/s^2 and the atmospheric pressure is 14.7psi. Electric current passes through the heating element, and the volume of the neon gas slowly increases by 0.071 m^3 while its pressure remains constant. The mass of the neon gas is 0.45 lbm, and its specific internal energy increases by 25 Btu/lbm. The neon gas and piston are at rest initially and finally. The piston-cylinder material is a ceramic composite and thus a good insulator. Friction between the piston and cylinder wall can be ignored, and the local acceleration of gravity is $g = 32.0 \text{ ft/s}^2$. Neon gas is consider to be the system.

- Determine the work done by the neon gas in BTU ?
- Determine the heat transfer from the heating element to the neon gas, in lbf-ft.
- Estimate the value of an external force F in N applied to the system to recover 30% of the heat input in (b) of which part of it was lost to work. This external force F reduces the final volume of the gas in (b) by 1.5 ft^3 .

$$\Delta U = Q + W \quad W = -P \Delta V \quad F = PA - Mg \frac{1}{g_c} \quad \text{Volume} = A \times \text{height}$$

Given

$$M_W = 70 \text{ lbm}$$

$$M_Z = 200 \text{ lbm}$$

$$P_d = 1.45 \text{ ft} \times \frac{12 \text{ in}}{1 \text{ ft}} = 17.4 \text{ in} \quad (5)$$

$$\text{local accel} = 32.170 \text{ ft/s}^2$$

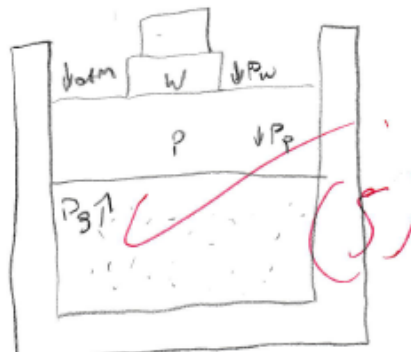
$$P_{atm} = 14.7 \text{ psf}$$

$$V_1 = 0.071 \text{ m}^3 \times \frac{61023.79 \text{ in}^3}{1 \text{ m}^3} = 4332.48 \text{ in}^3$$

$$M_{ssg} = 20.45 \text{ lbm}$$

$$\Delta U = 25 \text{ Btu/lbm}$$

$$\text{local accel} = 32.0 \text{ ft/s}^2$$



$$= 16.30 \text{ in} \times \frac{1}{12 \text{ in}} = 1.35 \text{ ft}$$

$$W = -P \Delta V \quad (5)$$

$$P_3 = F_3 / A$$

$$F_3 = \frac{1}{g_c} M \cdot g$$

$$\frac{1}{32.0 \text{ ft/s}^2} \cdot (200 + 70) \text{ lbm} \cdot 32.170 \text{ ft/s}^2$$

$$F_3 = 271.43 \text{ lbm} \quad (18)$$

$$A = \frac{\pi d^2}{4}$$

$$= \frac{\pi (1.45 \text{ ft})^2}{4}$$

$$= 1.65 \text{ ft}^2$$

$$P_3 = \frac{271.43 \text{ lbm}}{1.65 \text{ ft}^2} = 164.50 \text{ psf} \times \frac{144 \text{ in}^2}{1 \text{ ft}^2} = 23688.43 \text{ in}^2$$

$$W = -P \Delta V$$

$$= 14.7 \times 0.071 \text{ m}^3 \left| \frac{35.3147 \text{ ft}^3}{\text{m}^3} \right.$$

$$= 36.45 \text{ ft}^3 \left| \frac{144 \text{ in}^3}{\text{ft}^3} \right. (9)$$

$$= 5307.5 \text{ W/ft}^3$$

Convert to Btu

$$5307.5 \left| \frac{1 \text{ Btu}}{778} \right.$$

$$= \boxed{6.82 \text{ Btu}} (4)$$

No attempt on (b) and (c) of the problem

Prairie View A & M University, CHEG 2334: Chemical Engineering Thermodynamics I Fall 2021: Test 1, Wednesday, September 22, 2021. Instructor: Dr. Kazeem Olanrewaju

Closed Books

Name of Student: Baqel Wring

	Terms (A)	Concept (B)
1	System	Quantity of heat which when transferred to one pound mass of water raised its temperature one degree Fahrenheit
2	Specific Volume	The summation of the change in system energy and the change in the energy of the surrounding is
3	Potential energy	Energy added to a fluid as work is later transferred from the fluid as heat. Where is this energy between its addition to and transfer from the fluid?
4	Vacuum pressure	The units of force in centimeters-grams-seconds system of units is
5	Closed systems	Energy can neither be created nor destroyed, but rather transformed from one state to another
6	Kinetic energy	The real or imaginary surface that separates the system from its surroundings
7	Dimensions	A system where neither matter nor energy cross its boundaries is said to be
8	Work	Adjustable piston head of a closed system is consider :
9	Heat	The principle of energy conservation for all purely mechanical processes is affirm by
10	Temperature	There is transfer of energy across the boundary but no mass transfer
11	First law of thermodynamics	Energy in transition across the boundaries of a system due to a driving force other than temperature, and not associated with mass flowing across the boundary
12	Pressure	This is one of the energies associated with the system besides internal energy
13	Movable boundary	The difference between the absolute pressures of the atmosphere existing outside the measuring device and the absolute pressure of a system
14	Zero	A measure of the tendency of an object to spontaneously give up energy in form of heat to its surroundings is:
15	Isolated	$E_k = \frac{1}{2}mv^2$
16	Dyne	The reciprocal of the density of a liquid is
17	$\Delta K.E + \Delta P.E = 0$	Foot-pound force (f-lb _f) is one of the units used to describe a thermodynamics quantity and that parameter is:
18	Boundary	Measurable properties in thermodynamics are refer to as
19	BTU	A quantity of matter or a region in space chosen for study
20	Internal energy	This thermodynamics variable is a measure of equivalent height

17/20

14 ✓
14 ✓
25 ✓
16 ✓
11 ✓
18 ✓
15 ✓
13 ✓
17 ✓
5 ✓
8 ✓
9 X
4 ✓
10 ✓
6 ✓
2 ✓
12 X
7 ✓
1 ✓
3 X

BELOW AVERAGE

Below Average Student Original Graded Assignment

Prairie View A & M University, CHEG 2334: Thermodynamics I; Fall 2021: Test 1,
Wednesday, September 22, 2021, Instructor: Dr. Kazeem Olanrewaju
Part 2: Open Book (only hard copy of the Textbook)

Name of Student: Tyana Davis

22
80

Problem 1 (80 points)

Neon gas contained in a vertical piston-cylinder assembly on which rests a weight. The mass of weight and the piston are respectively 70 lbm and 200 lbm. The piston-cylinder's diameter is 1.45 ft. The local acceleration due to gravity is 32.170 ft/s² and the atmospheric pressure is 14.7 psi. Electric current passes through the heating element, and the volume of the neon gas slowly increases by 0.071 m³ while its pressure remains constant. The mass of the neon gas is 0.45 lbm, and its specific internal energy increases by 25 Btu/lbm. The neon gas and piston are at rest initially and finally. The piston-cylinder material is a ceramic composite and thus a good insulator. Friction between the piston and cylinder wall can be ignored, and the local acceleration of gravity is $g = 32.0 \text{ ft/s}^2$. Neon gas is considered to be the system.

- Determine the work done by the neon gas in BTU ?
- Determine the heat transfer from the heating element to the neon gas, in lb $\cdot$ ft.
- Estimate the value of an external force F in N applied to the system to recover 30% of the heat input in (b) of which part of it was lost to work. This external force F reduces the final volume of the gas in (b) by 1.5 ft³.

Tyana Days

Given

$$g = 32.0 \text{ ft/s}^2$$

$$M_p = 200 \text{ lbm}$$

$$M_w = 70 \text{ lbm}$$

$$D = 1.45 \text{ ft}$$

$$S = 32.170 \text{ ft/s}^2$$

$$P_A = 14.7 \text{ psi}$$

$$\Delta V = 0.071 \text{ m}^3$$

$$M_g = 0.45 \text{ lbm}$$

$$\Delta \hat{U} = 25 \text{ BTU/lbm}$$

$$A = 1.138 \text{ ft}^2$$

$$W = 6.216 \text{ ft/s}^2$$

Formulas:

$$F = W = \frac{1}{g_c} M g$$

$$W = -P \Delta V$$

$$\Delta \hat{U} = \frac{\Delta U}{M}$$

$$\Delta U = Q - W$$

$$\frac{1}{g_c} = \frac{1 \text{ lbf}}{32.174 \text{ lbm ft/s}^2}$$

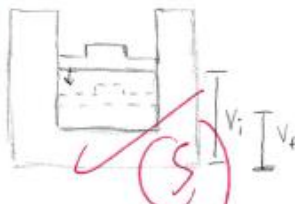
$$A = \frac{\pi D^2}{4}$$

$$a) A = \frac{\pi D^2}{4} = \frac{\pi (1.45 \text{ ft})^2}{4} = 1.13825 \text{ ft}^2$$

$$F = W = \frac{1}{g_c} M g = \frac{1 \text{ lbf}}{32.174 \text{ lbm ft/s}^2} (200 \text{ lbm})$$

$$= \frac{1 \text{ lbf}}{32.174 \text{ lbm ft/s}^2} \left\{ \frac{200 \text{ lbm}}{1 \text{ lbf}} \right\}$$

$$= \frac{200}{32.174 \text{ ft/s}^2} = 6.216 \text{ ft/s}^2$$



$$6.216 \text{ ft/s}^2 = -P (0.071 \text{ m}^3)$$

13
20

Prairie View A & M University, CHEG 2334: Chemical Engineering Thermodynamics I Fall 2021: Test 1, Wednesday, September 22, 2021. Instructor: Dr. Kazeem Olanrewaju

Closed Books

Name of Student:

Tyana Days

	Terms (A)	Concept (B)
1	System	Quantity of heat which when transferred to one pound mass of water raised its temperature one degree Fahrenheit 19 ✓
2	Specific Volume	The summation of the change in system energy and the change in the energy of the surrounding is 4 X
3	Potential energy	Energy added to a fluid as work is later transferred from the fluid as heat. Where is this energy between its addition to and transfer from the fluid? 20 ✓
4	Vacuum pressure	The units of force in centimeters-grams-seconds system of units is 16 ✓
5	Closed systems	Energy can neither be created nor destroyed, but rather transformed from one state to another 11 ✓
6	Kinetic energy	The real or imaginary surface that separates the system from its surroundings 18 ✓
7	Dimensions	A system where neither matter nor energy cross its boundaries is said to be 15 ✓
8	Work	Adjustable piston head of a closed system is consider : 13 ✓
9	Heat	The principle of energy conservation for all purely mechanical processes is affirm by 17 ✓
10	Temperature	There is transfer of energy across the boundary but no mass transfer 5 ✓
11	First law of thermodynamics	Energy in transition across the boundaries of a system due to a driving force other than temperature, and not associated with mass flowing across the boundary 8 ✓
12	Pressure	This is one of the energies associated with the system besides internal energy 6 X
13	Movable boundary	The difference between the absolute pressures of the atmosphere existing outside the measuring device and the absolute pressure of a system 14 ✓
14	Zero	A measure of the tendency of an object to spontaneously give up energy in form of heat to its surroundings is: 10 ✓
15	Isolated	$E_k = \frac{1}{2}mv^2$ 12 X
16	Dyne	The reciprocal of the density of a liquid is 9 X
17	$\Delta K.E + \Delta P.E = 0$	Foot-pound force (f·lb _f) is one of the units used to describe a thermodynamics quantity and that parameter is: 16 X
18	Boundary	Measurable properties in thermodynamics are refer to as 7 ✓
19	BTU	A quantity of matter or a region in space chosen for study 1 ✓
20	Internal energy	This thermodynamics variable is a measure of equivalent height 2 X

**CHEMICAL ENGINEERING THERMODYNAMICS I
FALL 2021**

HOMEWORK 1

TOPICS COVERED IN HOMEWORK 1

1. Dimensions and Units
2. Force
3. Temperature
4. Pressure
5. Work

**CHEMICAL ENGINEERING THERMODYNAMICS I
FALL 2021**

**SAMPLE HOMEWORK QUESTIONS, SOLUTION,
AND GRADING SCHEME FOR HOMEWORK**

CHEG 2334: THERMODYNAMICS I

HOMEWORK 1 (Due Date: 9/16/2021)

Name _____

Problem 1

A gas is contained in a 1.75(ft)-diameter vertical cylinder assembly by a piston on which a shaft whose mass is 20lb_m is attached. The mass of the piston is 255lb_m. The local acceleration of gravity is 32.169 ft/s² and the atmospheric pressure is 30.12 inHg. An external force F, is applied on the shaft to cause equilibration of the piston against the pressure exerted by the gas in the cylinder.

- a) Given that the gas pressure is 18.5 psia, estimate the magnitude of the applied force F on the shaft.
- b) Determine the work done in BTU, if the magnitude of the external force in (a) is increased by 25%, and the volume of the gas in the container decreases by 0.75 ft³.

Problem 2

- i. Helium gas enters an expander that provides a pressure ratio (exit pressure to inlet pressure) equal to 0.125. If a gauge indicates the gas pressure at the inlet is 49.5 psig, what is the absolute pressure, in psia, of the gas at the exit? Atmospheric pressure is 14.5 lb_f/in².
- ii. Prove the following relationship by Interpolation
 - a. $T (^{\circ}\text{F}) = 1.8 T (^{\circ}\text{C}) + 32$
 - b. $T (\text{R}) = T (^{\circ}\text{F}) + 459.67$

(1)

Thermodynamics I Homework 1 FALL 2021SOLUTIONProblem 1Given

Diameter of vertical piston cylinder = 1.75 ft

Mass of shaft attached to piston, $M_s = 20 \text{ lbm}$ Mass of piston, $M_p = 255 \text{ lbm}$ Local acceleration due to gravity, $g = 32.169 \text{ ft/s}^2$ Atmospheric pressure, $P_A = 30.12 \text{ inHg}$ An external force F is appliedFormulate

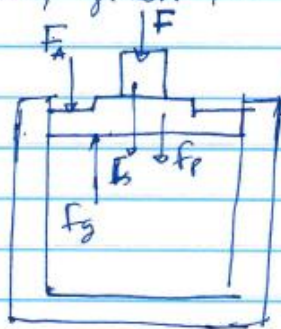
$$\vec{F} = \vec{W} = \frac{1}{g_c} \vec{M} \vec{g}; \quad P = \frac{F}{A}$$

$$W = -F \Delta l = -P \Delta V \quad \text{where } g_c = \frac{32.174 \text{ lbm ft/s}^2}{1 \text{ lbf}}$$

$$\Sigma F_i = 0$$

Solve:

(a) To estimate the magnitude of the applied F on the shaft, given that the gas pressure is 18.5 psia



(5) F_A = force due to atmospheric pressure

F : external force applied

F_p = force due to piston weight

F_s = force due to shaft weight

F_g = force due enclosed gas pressure

(2)

$$\therefore \Sigma F_c = 0$$

$$F_g = F_A + F_s + F_p + F$$

$$\therefore P_A = \frac{F_A}{A}$$

$$\therefore A = \frac{\pi D^2}{4} = \frac{3.142 \times 1.75^2 \text{ ft}^2}{4} = 2.41 \text{ ft}^2$$

$$P_A = 30.12 \text{ in Hg} = 14.7 \text{ psi}$$

(5)

$$\therefore A = \frac{2.41 \text{ ft}^2 \times 144 \text{ in}^2}{1 \text{ ft}^2} = 347.04 \text{ in}^2$$

$$\begin{aligned} \therefore F_A &= P_A \cdot A \\ &= 14.7 \frac{\text{lb}_f}{\text{in}^2} \times 347.04 \text{ in}^2 \end{aligned}$$

(10)

$$\therefore F_A = 5101.49 \text{ lb}_f$$

$$\therefore F_s = \frac{1}{g_c} M_s \cdot g = \frac{1 \text{ lb}_f}{32.174 \frac{\text{lbm ft}}{\text{s}^2}} \times 20 \text{ lbm} \times 32.169 \frac{\text{ft}}{\text{s}^2}$$

(10)

$$F_s = 19.997 \text{ lb}_f \Rightarrow F_s \approx 20.0 \text{ lb}_f$$

$$\therefore F_p = \frac{1}{g_c} M_p \cdot g = \frac{1 \text{ lb}_f}{32.174 \frac{\text{lbm ft}}{\text{s}^2}} \times 255 \text{ lbm} \times 32.169 \frac{\text{ft}}{\text{s}^2}$$

$$F_p = 254.96 \text{ lb}_f$$

(3)

$$F_g = P_g \cdot A \quad \text{where } P_g = 18.5 \text{ psia}$$

$$F_g = \frac{18.5 \text{ lbf}}{\text{in}^2} \times 347.04 \text{ in}^2$$

$$F_g = 6419.5 \text{ lbf}$$

(10)

$$\therefore F = F_g - (F_A + F_S + F_P)$$

$$F = 6419.5 \text{ lbf} - (5101.89 \text{ lbf} + 20 \text{ lbf} + 254.96 \text{ lbf})$$

$$F = 6419.5 \text{ lbf} - 5376.85 \text{ lbf}$$

$$F = 1043.05 \text{ lbf}$$

(5)

$$F = \frac{1043.05 \text{ lbf}}{1 \text{ lbf}} \times \frac{4.45 \text{ N}}{1 \text{ lbf}} = 4641.57 \text{ N}$$

(b) To determine the Work Done in Btu, if the Magnitude of the external force in (a) is increased by 25%, ~~this~~ and the Volume of the gas in the container decreases by 0.75 ft^3

$$\text{Initial force, } F_i = 1043.05 \text{ lbf}$$

$$\text{Final force, } F_f = 1.25 \times 1043.05 \text{ lbf}$$

$$F_f = 1303.81 \text{ lbf}$$

(5)

$$\text{Work Done} = -P \Delta V$$

= -

(4)

$$\text{Work done} = - \frac{[1303.81 - 1043.05] \text{ lb}_f}{347.04 \text{ in}^2} \times -0.75 \text{ ft}^3$$

$$= \frac{-260.76 \text{ lb}_f}{2.41 \text{ ft}^2} \times -0.75 \text{ ft}^3$$

$$\text{Work done} = \frac{81.15 \text{ lb}_f \cdot \text{ft}}{1 \text{ lb}_f \cdot \text{ft}} \left\{ \begin{array}{l} 0.001285 \\ 1 \end{array} \right.$$

$$\boxed{\text{Work done} = 0.1043 \text{ Btu}} \quad (5)$$

Problem 2

Given:

Pressure ratio (exit pressure to inlet pressure) = 0.125

Gauge pressure at the inlet = 49.5 psig

Atmospheric pressure = 14.5 lb_f/in²

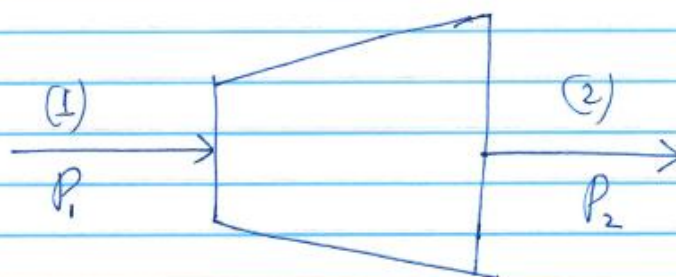
Formulate

$$P_{\text{absolute}} = P_{\text{gauge}} + P_{\text{atmospheric}}$$

(5)

To solve

(i) To obtain what the absolute pressure, in psia, of the gas at the exit



$$\therefore \frac{P_2}{P_1} = 0.125$$

(10)

$\therefore P_1 = \text{Inlet pressure} = 49.5 \text{ psig} + P_{\text{atmospheric}}$

$$P_1 = 49.5 \text{ psig} + 14.5 \text{ psi}$$

$$\therefore P_1 = 64 \text{ psia}$$

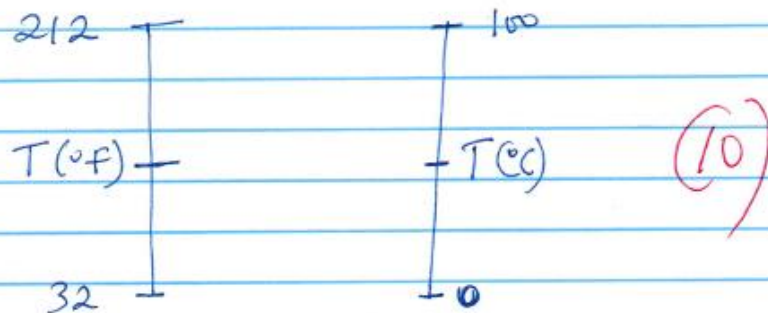
$$\therefore P_2 = 0.125 \times 64 \text{ psia}$$

$$P_2 = 8 \text{ psia}$$

6)

(i) To prove the following relationship by interpolation

$$(a) T(^{\circ}F) = 1.8T(^{\circ}C) + 32$$



$$\therefore \frac{212 - 32}{T(^{\circ}F) - 32} = \frac{100 - 0}{T(^{\circ}C) - 0}$$

$$\therefore \frac{180}{T(^{\circ}F) - 32} = \frac{100}{T(^{\circ}C)}$$

$$(T(^{\circ}F) - 32) \times 100 = 180 T(^{\circ}C)$$

$$T(^{\circ}F) - 32 = 1.8 T(^{\circ}C)$$

$$\therefore T(^{\circ}F) = 1.8 T(^{\circ}C) + 32$$

ABOVE AVERAGE

Above Average Student Original Graded Assignment

CHEG 2334: THERMODYNAMICS I

HOMEWORK 1 (Due Date: 9/16/2021)

Name : Laury Mengue

Problem 1

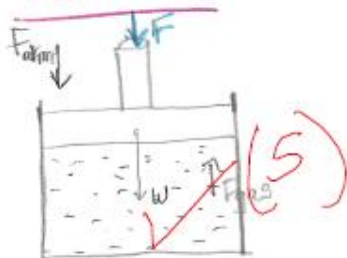
A gas is contained in a 1.75(ft)-diameter vertical cylinder assembly by a piston on which a shaft whose mass is 20lb_m is attached. The mass of the piston is 255lb_m. The local acceleration of gravity is 32.169 ft/s² and the atmospheric pressure is 30.12 inHg. An external force F, is applied on the shaft to cause equilibration of the piston against the pressure exerted by the gas in the cylinder.

- a) Given that the gas pressure is 18.5 psia, estimate the magnitude of the applied force F on the shaft.
- b) Determine the work done in BTU, if the magnitude of the external force in (a) is increased by 25%, and the volume of the gas in the container decreases by 0.75 ft³.

Problem 2

- i. Helium gas enters an expander that provides a pressure ratio (exit pressure to inlet pressure) equal to 0.125. If a gauge indicates the gas pressure at the inlet is 49.5 psig, what is the absolute pressure, in psia, of the gas at the exit? Atmospheric pressure is 14.5 lb_f/in².
- ii. Prove the following relationship by Interpolation
 - a. $T(^{\circ}\text{F}) = 1.8 T(^{\circ}\text{C}) + 32$
 - b. $T(\text{R}) = T(^{\circ}\text{F}) + 459.67$

Problem 1



Given: Diameter = 1.75 ft.

- Piston mass = 255 lbm

- Shaft mass = 20 lbm

Atmospheric pressure = 30.12 in Hg =

$$30.12 \text{ in Hg} \times \frac{3386.4 \text{ N} \cdot \text{m}^{-2}}{1 \text{ in Hg}}$$

$$\text{Atmospheric } P = 101,998.37 \text{ N} \cdot \text{m}^{-2}$$

- Gas pressure = 18.5 psia

$$\Rightarrow 18.5 \text{ psia} \times \frac{6895 \text{ Pa}}{1 \text{ psi}} \times \frac{1 \text{ N} \cdot \text{m}^{-2}}{1 \text{ Pa}}$$

$$\Rightarrow 127,557 \text{ N} \cdot \text{m}^{-2}$$

a) Calculation of force F.

According to the free body diagram of the piston under condition of Equilibrium:

$$F_{\text{gas}} = F_{\text{arm}} + F_w + F \Rightarrow F = F_{\text{gas}} - F_{\text{arm}} - F_w$$

$$\bullet F_{\text{gas}} = \text{Pressure gas} \times \text{Area piston} \quad \text{Area} = \pi r^2 = \pi \left(\frac{D}{2}\right)^2 = \frac{\pi}{4} D^2$$

$$= 127,557 \text{ N} \cdot \text{m}^{-2} \times 0.223 \text{ m}^2$$

$$F_{\text{gas}} = 28,434.5 \text{ N}$$

$$= \frac{\pi}{4} \times (1.75 \text{ ft})^2$$

$$= 2.4 \text{ ft}^2$$

$$= 2.4 \text{ ft}^2 \times \frac{1 \text{ m}^2}{3.281^2 \text{ ft}^2} = 0.223 \text{ m}^2$$

$$\bullet F_{\text{arm}} = P_{\text{atm}} \times \text{Area piston}$$

$$= 101,998.37 \times 0.223$$

$$F_{\text{arm}} = 22,745.6 \text{ N}$$

$$\bullet F_w = \text{Force due to weight of Piston and shaft.}$$

$$= (255 \text{ lbm} + 20 \text{ lbm})$$

$$= 275 \text{ lbm} \times \frac{1 \text{ lbf}}{1 \text{ lbm}} \times \frac{1 \text{ N}}{4.448 \text{ lbf}} = 4.448 \text{ N}$$

$$F_w = 1223.26 \text{ N}$$

$$F = F_{\text{gas}} - F_{\text{atm}} - F_w$$

$$F = 28,445 \text{ N} - 22,745.6 \text{ N} - 1223.6 \text{ N}$$

$$F = 4475.76 \text{ N} \quad (5)$$

b) Work = $F_{\text{reduced}} \times \Delta h$.

$$F_{\text{reduced}} = 4475.76 \times (0.75) = 3356.8 \text{ N} \quad \left| \begin{array}{l} \text{Because } F \\ \text{is reduced} \\ \text{by 25\%} \end{array} \right.$$

$$\begin{aligned} \Delta V &= \pi r^2 \Delta h \Rightarrow \Delta h = \frac{\Delta V}{\pi r^2} \\ &= \frac{0.75 \text{ ft}^3}{\pi \times (1.75 \text{ ft})^2} \\ &= \frac{0.75 \text{ ft}^3}{\pi \times 3.06 \text{ ft}^2} \\ &= 0.078 \text{ ft} = 0.0238 \text{ m} \end{aligned}$$

$$W = 3356.8 \text{ N} \times 0.0238 \text{ m}$$

$$W = 79.9 \text{ N} \cdot \text{m}$$

$$79.9 \text{ N} \cdot \text{m} \times \frac{1 \text{ BTU}}{1055.06 \text{ N} \cdot \text{m}}$$

$$W = 0.0757 \text{ BTU} \quad (4)$$

Problem 2

i. Given: Pressure exit Gauge = 0.125

Gauge pressure out

• Pressure inlet (gauge) = 49.5 psig

• Atmospheric pressure is $14.5 \text{ lbf/in}^2 = 14.5 \text{ psi}$

$$\text{Pressure gauge out} = 0.125 \times 49.5 = 6.187 \text{ psig}$$

We know:

Absolute pressure = gauge pressure + atmospheric pressure

$$= 6.187 \text{ psig} + 14.5 \text{ psi}$$

$$= 20.687 \text{ psia}$$

ii. Prove by interpolation that:

$$a) T(^{\circ}\text{F}) = 1.8 T(^{\circ}\text{C}) + 32$$

$$\text{Interpolation formula: } \frac{y - y_0}{x - x_0} = \frac{y_1 - y_0}{x_1 - x_0}$$

Let's choose 2 points:

Pelsius scale: melting point of ice = 0°C

Boiling point of water = 100°C

Fahrenheit scale: melting point of ice = 32°C

Boiling point of water = 212°F

$$\frac{F - 32}{C - 0} = \frac{212 - 32}{100 - 0} \Rightarrow F - 32 = \frac{(212 - 32)C}{100}$$

$$F - 32 = \frac{180}{100} C$$

$$F = 1.8C + 32$$

$$b) T(R) = T(^{\circ}\text{F}) + 459.67$$

For Rankine scale, melting point of ice = 491.67 R

boiling point of water = 671.67 R

By same principle as previously stated above.

$$\frac{R - 491.67}{F - 32} = \frac{671.62 - 491.67}{212 - 32}$$

$$\Rightarrow \frac{R - 491.67}{F - 32} = \frac{179.95}{180} \approx 1.$$

$$\Rightarrow R - 491.67 = F - 32.$$

$$R = F - 32 + 491.67$$

$$R = F + 459.67$$

AVERAGE

Average Student Original Graded Assignment

1. given: $d = 1.75 \text{ ft}$ $m_s = 20 \text{ lb}$ $m_p = 255 \text{ lb}$ $a_g = 32.169 \text{ ft/s}^2$
 $p_a = 30.12 \text{ inHg}$ $p_g = 18.5 \text{ psi}$

$F_g = F + F_s + F_p + F_a \rightarrow F = F_g - F_{sp} - F_a$

$A = \frac{\pi d^2}{4} = \frac{\pi (1.75)^2}{4} = 2.4$

$m_s + m_p = 20 \text{ lb} + 255 \text{ lb} = 275 \text{ lb} = m_{sp}$

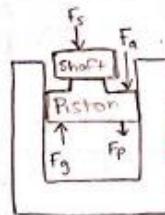
$F_{sp} = \frac{1}{g_c} (m_{sp}) g$
 $= \frac{1}{g_c} (275 \text{ lb}) (32.169 \text{ ft/s}^2)$
 $= 8,846.48$

$F_a = 30.12 \text{ inHg} (2.4)$
 $F_a = 7229$

$F_g = 18.5 \text{ psi} (2.4)$
 $F_g = 444$

$F = 8,846.48 - 7229 - 444$

$F = 1173.48 \text{ lb}_f$



b.

a.

given: $P_F/P_0 = 0.125$ $P_0 = 49.5 \text{ psi}$ $P_a = 14.5 \text{ lbf/in}^2$

$$P_F = 0.125(49.5)$$

$$P_F = 6.19 \text{ psi}$$

$$14.5 + 6.19 \text{ psi} = \underline{20.69 \text{ psi}}$$

a. $T(^{\circ}\text{F}) = 1.8(^{\circ}\text{C}) + 32$

melting point $0^{\circ}\text{C} \rightarrow 32^{\circ}\text{F}$

boiling point $100^{\circ}\text{C} \rightarrow 212^{\circ}\text{F}$

$$\frac{C-0}{100-0} = \frac{F-32}{212-32}$$

$$\frac{C}{100} = \frac{F-32}{180}$$

$$F-32 = 1.8C$$

$$F = 1.8C + 32$$

$$T(^{\circ}\text{F}) = 1.8T(^{\circ}\text{C}) + 32$$

b. $T(^{\circ}\text{R}) = T(^{\circ}\text{F}) + 459.67$

melting point ^(ice) 491.67°R

boiling point _(water) 671.67°R

$$\frac{R-491.67}{(671.67-491.67)} = \frac{F-32}{(212-32)}$$

$$\frac{R-491.67}{179.95} = \frac{F-32}{180}$$

$$R-491.67 = F-32$$

$$R = F-32+491.67$$

$$R = F+459.67$$

BELOW AVERAGE

Below Average Student Original Graded Assignment

CHEG 2334: THERMODYNAMICS I
HOMEWORK 1 (Due Date: 9/16/2021)

(57/100)

Name _____

Problem 1

A gas is contained in a 1.75(ft)-diameter vertical cylinder assembly by a piston on which a shaft whose mass is 20lb_m is attached. The mass of the piston is 255lb_m . The local acceleration of gravity is 32.169 ft/s^2 and the atmospheric pressure is 30.12 inHg. An external force F , is applied on the shaft to cause equilibration of the piston against the pressure exerted by the gas in the cylinder.

- Given that the gas pressure is 18.5 psia, estimate the magnitude of the applied force F on the shaft.
- Determine the work done in BTU, if the magnitude of the external force in (a) is increased by 25%, and the volume of the gas in the container decreases by 0.75 ft^3 .

Problem 2

- Helium gas enters an expander that provides a pressure ratio (exit pressure to inlet pressure) equal to 0.125. If a gauge indicates the gas pressure at the inlet is 49.5 psig, what is the absolute pressure, in psia, of the gas at the exit?
Atmospheric pressure is $14.5\text{ lb}_f/\text{in}^2$.
- Prove the following relationship by Interpolation
 - $T(^{\circ}\text{F}) = 1.8 T(^{\circ}\text{C}) + 32$
 - $T(\text{R}) = T(^{\circ}\text{F}) + 459.67$

$$1.75 = D$$

$$20 = \text{shaft mass}$$

$$255 = \text{piston mass}$$

$$\text{accel} = 32.164$$

$$\text{pressure} = \frac{30.12 \text{ in Hg}}{2.036} = 14.79 \text{ psi}$$

$$F_g = F_a + F_w + F_p$$

$$P_A = (P - P_{\text{atm}})$$

$$= (18.5 - 14.79)$$

$$= 3.71 \text{ psi}$$

$$F_{pw} = \frac{1}{g_c} (m_p + m_s) \cdot g$$

$$\frac{1}{32.174 \text{ lbm}} (255) (32.164) = 274.95$$

$$F_A = P \cdot A = 3.71 \cdot 346.36 = 1284.44$$

$$A = \frac{\pi d^2}{4} = \frac{\pi (1.75)^2}{4}$$

$$F = 1284.44 + 274.95 \text{ lb}$$

$$a) \sqrt[11]{1559.84 \text{ lbs}}$$

$$b) \text{BLANK} \cdot \frac{\pi (1.75)^3}{6} =$$

$$F(1.25) = 1559.84 \cdot (1.25) = 38.995$$

$$P = \frac{F}{A} = \frac{38.995}{346.36} = .11$$

$$.11 \cdot \frac{\pi (1.75)^3}{6} \cdot .75 =$$

$$b) \boxed{.23}$$

i) What is the absolute pressure in psia

$$\frac{p_{\text{exit}}}{p_a} = 0.125$$

$$49.5 = \text{gauge pressure}$$

$$14.5 \text{ psia} = \text{Atmospheric pressure}$$

(7)

$$0.125 \cdot 49.5 = 6.1875 = p_{\text{exit}}$$

$$(14.5 + 6.1875) = \boxed{20.6875 \text{ psia}}$$

ii)

$$\frac{y - y_0}{y_1 - y_0} = \frac{x - x_0}{x_1 - x_0}$$

← boiling point of ice melting

← boiling point of water

$$\frac{C - 0}{(100 - 0)} = \frac{F - 32}{(212 - 32)}$$

$$F - 32 = 1.8C$$

$$F = 1.8C + 32$$

$$\boxed{T(^{\circ}\text{F}) = 1.8T(^{\circ}\text{C}) + 32}$$

$$\frac{R - 491.67}{671.67 - 491.67} = \frac{F - 32}{212 - 32}$$

$$R - 491.67 = 0.99F - 32 = (F - 32)$$

$$\boxed{R = F - 32 + 491.67 = F + 459.67}$$

CHEMICAL ENGINEERING THERMODYNAMICS I
FALL 2021

MIDTERM EXAM

TOPICS COVERED IN MIDTERM EXAM

1. Dimensions and Units
2. The First Law of Thermodynamics
3. Energy Balance for Closed Systems
4. Constant Volume and Constant Pressure Processes
5. Enthalpy
6. Heat Capacity
7. Mass and Energy Balance for Open Systems
8. Volumetric Properties of Pure Fluids

**CHEMICAL ENGINEERING THERMODYNAMICS I
FALL 2021**

**SAMPLE MIDTERM EXAM QUESTIONS, SOLUTION,
AND GRADING SCHEME FOR MIDTERM EXAM**

You should not reference to or have access to your class notes, laptop, tablet, cell phone, smart phone, and any other electronic gadgets. Open Book

Name of Student: _____

Problem 1 (30 points)

Nitrogen gas (N_2) is confined in a cylinder by a piston, and the atmosphere exerts a pressure of 14.7 lbf/in^2 on the top of the piston, which has a mass of 225 lbm and a face area of 1 ft^2 . The mass of N_2 is 1.5 lbm and initially Nitrogen gas occupies a volume of 0.0045 m^3 . The volume of Nitrogen gas slowly decreases to 1 liter as energy with a magnitude of 2.4 kJ is slowly removed by heat transfer. The piston–cylinder material is a ceramic composite and thus a good insulator. Friction between the piston and cylinder wall can be ignored, and the local acceleration of gravity is $g = 32.0 \text{ ft/s}^2$. Nitrogen gas is considered to be the system

- a) Determine the work done by the Nitrogen gas in Btu
- b) Determine the change in specific internal energy of the Nitrogen gas, in Btu/lbm.

Problem 2 (30 points)

Steam enters a turbine operating at steady state at 2 MPa, 350°C with a velocity of 100 m/s. Saturated vapor exits at 0.1 MPa and a velocity of 50 m/s. The elevation of the inlet is 3 m higher than at the exit. The mass flow rate of the steam is 15 kg/s, and the power developed is 7 MW. Let $g = 9.81 \text{ m/s}^2$.

Inlet specific enthalpy = 3138.6 kJ/kg	Outlet specific enthalpy = 417.511 kJ/kg
Inlet specific volume = $0.1386 \text{ m}^3/\text{kg}$	Outlet specific volume = $0.001043 \text{ m}^3/\text{kg}$

Determine:

- a) The area at the inlet, in m^2 ,
- b) The volumetric flow rate at the outlet, in cm^3/s , and
- c) The rate of heat transfer between the turbine and its surroundings, in Btu-ft/h .

Problem 3 (20 points)

In the following, take $C_v = 35.4$ and $C_p = 44.5 \text{ J mol}^{-1} \text{ } ^\circ\text{C}^{-1}$ for carbon disulfide (CS_2) gas: 264 g of carbon disulfide at 300°C is contained in a piston/cylinder arrangement. How much heat must be extracted from this system, which is kept at constant pressure, to cool it to 50°C if the heat capacity of the piston and cylinder is neglected?

$C=12$, $S=32$.

Prairie View A & M University, CHEG 2334: Chemical Engineering Thermodynamics I Fall 2021: Mid-Term Exam, Wednesday, October 20, 2021. Instructor: Dr. Kazeem Olanrewaju

Closed Books

Name of Student: _____

	Terms (A)	Concept (B)	Answer
1	Isotherms	The units of force in American Engineering System (AES) of units is :	
2	Internal energy	A mathematical model that relates pressure, temperature and volume is called	
3	zero	In a constant pressure closed process, quantity of energy transfer as heat is equal to change in	
4	Continuity equation	In energy balance, the difference between enthalpy and flow work is describe by a term called	
5	Length	An example of a control volume that includes shaft work in its energy balance	
6	Frictionless	An example of a supercritical fluid is	
7	Dimensions	The mass balance for an open system is describe by :	
8	Equation of state	$\frac{\partial U}{\partial T}$ is a mathematical model for depicting the specific heat capacity of what type of closed process	
9	Gibbs Phase Rule	An increase in the energy of the system will result in a corresponding decrease in the energy of the	
10	Boundary	The conditions of the mass within the control volume and at the boundary do not vary with time. The process is said to be at	
11	Turbine	An extensive property is transform into intensive by dividing the value of the property with	
12	Steady state	macroscopic characteristic of a system such as mass, volume, energy, pressure, and temperature of the system	
13	Constant volume	Heat transfer into the control volume of an open system is	
14	Enthalpy	The real or imaginary surface that separates the system from its surroundings	
15	Environment	All additive terms on both sides of the equation must have the same	
16	Pound force	The thermodynamic concepts responsible for determining the number of properties needed to fix a thermodynamic system	
17	Positive	One of the features of a reversible process is that it is	
18	Property	The change in internal energy of a reversible process is	
19	Amount	What is the property by which temperature is calibrated in thermometer	
20	Air	The line of proportionality between pressure and volume of fluid as depicted on a PV-phase diagram is describe as	

(1)

THERMODYNAMICS I MIDTERM EXAM FALL 2021 SOLUTION

Problem 1

Given:

Atmospheric pressure, $P_A = 14.7 \text{ lb}_f/\text{in}^2$

Mass of piston head, $M_p = 225 \text{ lbm}$

Face area = $1 \text{ ft}^2 = A$

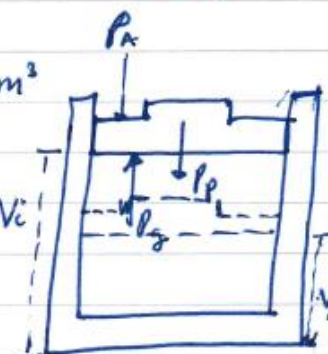
Mass of N_2 , $M_g = 1.5 \text{ lbm}$

Initial volume of gas, $V_i = 0.005 \text{ m}^3$

Final volume of gas, $V_f = 1 \text{ liter}$

Heat transfer, $Q = 2.4 \text{ kJ}$

Local acceleration, $g = 32 \text{ ft/s}^2$



Formulate

$$F = \frac{1}{g_c} mg, \quad P = \frac{F}{A}, \quad \Delta u = Q + W$$

$$F_r = \sum F_i, \quad P_r = \sum P_i, \quad W = -P \Delta V$$

Solve

(a) To determine the Work done by the Nitrogen gas in Btu

$$W = \Delta u - Q$$

(2)

$$P_A = 14.7 \text{ lb}_f/\text{in}^2$$

$$P_p = \frac{F_p}{A} \quad \text{but} \quad F_p = \frac{1}{g_c} M_p g \quad (5)$$

$$F_p = \frac{1 \text{ lb}_f}{32.174 \text{ lb}_m \cdot \cancel{\text{ft}}/\text{s}^2} \times \frac{225 \text{ lb}_m \times 32 \cancel{\text{ft}}/\text{s}^2}{1}$$

$$F_p = 223.78 \text{ lb}_f$$

$$\therefore P_p = \frac{F_p}{A} = \frac{223.78 \text{ lb}_f}{1 \cancel{\text{ft}}^2} \times \frac{1 \cancel{\text{ft}}^2}{144 \text{ in}^2} = 1.55 \frac{\text{lb}_f}{\text{in}^2}$$

$$\therefore P_T = P_p + P_A = P_g.$$

$$\therefore P_T = 1.55 \text{ lb}_f/\text{in}^2 + 14.7 \text{ lb}_f/\text{in}^2$$

$$\therefore \boxed{P_T = 16.25 \text{ lb}_f/\text{in}^2} \quad (5)$$

$$\therefore W = -P \Delta V \quad \text{while} \quad \Delta V = V_f - V_i$$

$$V_i = 0.0045 \text{ m}^3$$

$$V_f = 1 \text{ L} = 0.001 \text{ m}^3$$

$$\therefore \Delta V = V_f - V_i = 0.001 \text{ m}^3 - 0.0045 \text{ m}^3 = -0.0035 \text{ m}^3$$

$$\therefore \Delta V = \frac{-0.0035 \text{ m}^3 \times 35.3145 \cancel{\text{ft}}^3}{1 \cancel{\text{m}}^3}$$

$$\Delta V = -0.1236 \cancel{\text{ft}}^3$$

(3)

$$\therefore W = -P_f \Delta V$$

$$\therefore W = -16.25 \frac{\text{lb}_f}{\text{in}^2} \left\{ \frac{-0.1236 \text{ ft}^3}{1} \right\} \frac{144 \frac{\text{in}^2}{\text{ft}^2}}{778.169 \frac{\text{ft} \cdot \text{lb}_f}{\text{Btu}}} \quad (5)$$

$$\therefore W = \frac{239.224 \text{ ft} \cdot \text{lb}_f}{1} \left\{ \frac{1 \text{ Btu}}{778.169 \text{ ft} \cdot \text{lb}_f} \right\}$$

$$W = 0.372 \text{ Btu}$$

Work done by the environment on the Nitrogen gas in Btu

(6) To determine the change in specific internal energy of the Nitrogen gas, in Btu/lbm

$$\therefore \Delta U = Q + W$$

$$\therefore \hat{\Delta U} = \frac{\hat{Q}}{m_2} + \frac{\hat{W}}{m_2} \quad (5)$$

$$\therefore Q = \frac{2.4 \text{ kJ}}{1.05506 \text{ kJ}} \times 1 \text{ Btu} = 2.275 \text{ Btu}$$

$$Q = -2.275 \text{ Btu (Energy removed from the system)}$$

$$\Delta U = [-2.275 + 0.372] \text{ Btu}$$

$$\Delta U = -1.903 \text{ Btu} \quad (5)$$

$$\therefore \hat{\Delta U} = \frac{-1.903 \text{ Btu}}{1.5 \text{ lbm}} = -1.269 \frac{\text{Btu}}{\text{lbm}}$$

(4)

$$\Delta \hat{U} = -1.269 \frac{\text{kJ}}{\text{kg}}$$

Problem 2

Given:

$$P_1 = 2 \text{ MPa}$$

$$T_1 = 350^\circ \text{C}$$

$$u_1 = 100 \text{ m/s}$$

$$P_2 = 0.1 \text{ MPa}$$

$$u_2 = 50 \text{ m/s}$$

$$\Delta z = 3 \text{ m}$$

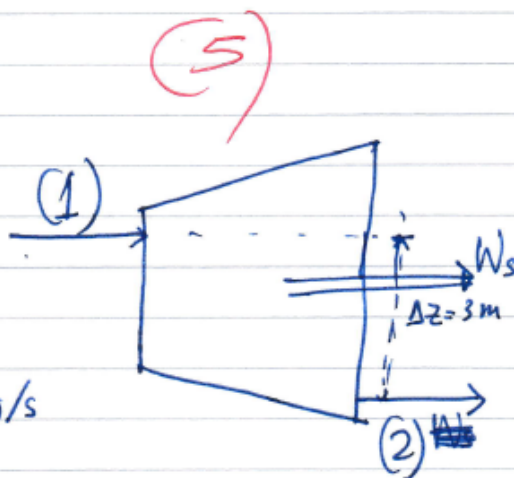
$$\text{Mass flow rate, } \dot{m} = 15 \text{ kg/s}$$

$$W_s, (\text{power}) = 7 \text{ MW}$$

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

$$h_1 = 3138.6 \text{ kJ/kg}; \quad h_2 = 417.511 \text{ kJ/kg}$$

$$v_1 = 0.1386 \text{ m}^3/\text{kg}; \quad v_2 = 0.001043 \text{ m}^3/\text{kg}$$



Formulate

$$A = \frac{\pi D^2}{4}$$

$$\rho = \frac{1}{v}; \quad \dot{m} = \rho u A \quad (5)$$

$$\frac{d(mU)}{dt} = -\Delta \left[\left(h + \frac{1}{2} u^2 + zg \right) \dot{m} \right]_K + \dot{Q} + \dot{W}_s$$

(8)

Solve(a) To obtain area at the inlet, in m^2

$$\therefore \dot{m} = \rho u A$$

$$\therefore \dot{m} = \frac{uA}{V} = \frac{u_1 A_1}{V_1} = \frac{100 \text{ m/s} \times A}{0.1386 \frac{m^3}{kg}} \quad (5)$$

$$\therefore 15 \text{ kg/s} = \frac{100 \text{ m/s} \times A}{0.1386 \frac{m^3}{kg}}$$

$$\therefore A = \frac{15 \text{ kg/s} \times 0.1386 \frac{m^3}{kg}}{100 \text{ m/s}}$$

$$A = 0.0208 \text{ m}^2$$

(b) The volumetric flow rate at the outlet, in cm^3/s

$$\text{Volume flow rate} = \text{Mass flow rate} \times \text{Specific volume} \quad (5)$$

$$= 15 \text{ kg/s} \times 0.001043 \frac{m^3}{kg}$$

$$= 0.01565 \frac{m^3}{s} \left| \frac{10^6 \text{ cm}^3}{1 \text{ m}^3} \right|$$

$$\text{Volumetric flow rate} = 15650 \frac{cm^3}{s}$$

(6)

(c) To obtain the rate of heat transfer between the turbine and its surroundings, in kJ/s

at steady state, Accumulation = 0

$$\frac{d(mU)}{dt} = -\Delta \left[\left(H + \frac{1}{2}U^2 + zg \right) \dot{m} \right]_{fs} + \dot{Q} + \dot{W}_s \quad (10)$$

$$- \left[\left(H_2 - H_1 \right) + \left(\frac{U_2^2}{2} - \frac{U_1^2}{2} \right) + (z_2 - z_1)g \right] \dot{m} + \dot{Q} + \dot{W}_s = 0$$

$$- \left[(417.511 - 3138.6) + \left(\frac{50^2}{2} - \frac{100^2}{2} \right) + (3 \text{ m} \times 9.81 \frac{\text{m}}{\text{s}^2}) \right] 15 \frac{\text{kg}}{\text{s}} + \dot{Q} + (-7000 \text{ kJ/s}) = 0$$

$$- \left[\left(-2721.09 \frac{\text{kJ}}{\text{kg}} \right) + \left(-3750 \frac{\text{m}^2}{\text{s}^2} \right) + \left(-29.43 \frac{\text{m}^2}{\text{s}^2} \right) \right] 15 \frac{\text{kg}}{\text{s}} + \dot{Q} + (-7000 \text{ kJ/s}) = 0$$

$$\left[2721.09 \frac{\text{kJ}}{\text{kg}} + 3779.43 \frac{\text{m}^2}{\text{s}^2} \right] \frac{1 \text{ kJ/kg}}{1000 \frac{\text{m}^2}{\text{s}^2}} 15 \frac{\text{kg}}{\text{s}} + \dot{Q} - 7000 \text{ kJ/s} = 0$$

$$\left[2721.09 \frac{\text{kJ}}{\text{kg}} + 3.7794 \frac{\text{kJ}}{\text{kg}} \right] 15 \frac{\text{kg}}{\text{s}} + \dot{Q} - 7000 \frac{\text{kJ}}{\text{s}} = 0$$

$$40873.04 \frac{\text{kJ}}{\text{s}} + \dot{Q} - 7000 \frac{\text{kJ}}{\text{s}} = 0$$

$$\dot{Q} + 33873.04 \frac{\text{kJ}}{\text{s}} = 0$$

(8)

Solve

To solve for the quantity of heat that must be extracted from this system at constant pressure.

$$\therefore Q = n C_p \Delta T$$

$$\therefore n = \frac{\text{Mass of CS}_2}{\text{MW of CS}_2}$$

(5)

$$\begin{aligned} \therefore \text{MW of CS}_2 &= 12 + (32 \times 2) \\ &= 12 + 64 = 76 \text{ g/mole} \end{aligned}$$

$$\therefore n = \frac{264 \text{ g}}{76 \text{ g/mole}} = 3.474 \text{ mole}$$

(5)

$$\therefore Q = 3.474 \text{ mole} \times \frac{448.5 \text{ J}}{\text{mole} \cdot ^\circ\text{C}} \times (50 - 300)^\circ\text{C}$$

$$\therefore Q = -38648.25 \text{ J}$$

(5)

$$\therefore \boxed{Q = -38.648 \text{ kJ}}$$

(8)

Solve

To solve for the quantity of heat that must be extracted from this system at constant pressure.

$$\therefore Q = n C_p \Delta T$$

$$\therefore n = \frac{\text{Mass of CS}_2}{\text{MW of CS}_2}$$

(5)

$$\begin{aligned} \therefore \text{MW of CS}_2 &= 12 + (32 \times 2) \\ &= 12 + 64 = 76 \text{ g/mole} \end{aligned}$$

$$\therefore n = \frac{264 \text{ g}}{76 \text{ g/mole}} = 3.474 \text{ mole}$$

(5)

$$\therefore Q = 3.474 \text{ mole} \times \frac{448.5 \text{ J}}{\text{mole} \cdot ^\circ\text{C}} \times (50 - 300)^\circ\text{C}$$

$$\therefore Q = -38648.25 \text{ J}$$

(5)

$$\therefore \boxed{Q = -38.648 \text{ kJ}}$$

Prairie View A & M University, CHEG 2334: Chemical Engineering Thermodynamics I Fall 2021: Mid-Term Exam, Wednesday, October 20, 2021. Instructor: Dr. Kazeem Olanrewaju

Closed Books

Name of Student: _____

	Terms (A)	Concept (B)	Answer
1	Isotherms	The units of force in American Engineering System (AES) of units is :	16
2	Internal energy	A mathematical model that relates pressure, temperature and volume is called	8
3	zero	In a constant pressure closed process, quantity of energy transfer as heat is equal to change in	14
4	Continuity equation	In energy balance, the difference between enthalpy and flow work is describe by a term called	12
5	Length	An example of a control volume that includes shaft work in its energy balance	11
6	Frictionless	An example of a supercritical fluid is	20
7	Dimensions	The mass balance for an open system is describe by :	4
8	Equation of state	$\frac{\partial U}{\partial T}$ is a mathematical model for depicting the specific heat capacity of what type of closed process	13
9	Gibbs Phase Rule	An increase in the energy of the system will result in a corresponding decrease in the energy of the	15
10	Boundary	The conditions of the mass within the control volume and at the boundary do not vary with time. The process is said to be at	12
11	Turbine	An extensive property is transform into intensive by dividing the value of the property with	19
12	Steady state	macroscopic characteristic of a system such as mass, volume, energy, pressure, and temperature of the system	18
13	Constant volume	Heat transfer into the control volume of an open system is	17
14	Enthalpy	The real or imaginary surface that separates the system from its surroundings	10
15	Environment	All additive terms on both sides of the equation must have the same	7
16	Pound force	The thermodynamic concepts responsible for determining the number of properties needed to fix a thermodynamic system	9
17	Positive	One of the features of a reversible process is that it is	6
18	Property	The change in internal energy of a reversible process is	3
19	Amount	What is the property by which temperature is calibrated in thermometer	5
20	Air	The line of proportionality between pressure and volume of fluid as depicted on a PV-phase diagram is describe as	1

ABOVE AVERAGE

Above Average Student Original Graded Assignment

Prairie View A & M University, CHEG 2334: Chemical Engineering Thermodynamics I Fall 2021: Mid-Term Exam, Monday, October 20, 2021. Instructor: Dr. Kazeem Olanrewaju

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Name of Student: FAYOLLOUIS

77
80

Problem 1 (30 points)

Nitrogen gas (N_2) is confined in a cylinder by a piston, and the atmosphere exerts a pressure of 14.7 lbf/in^2 on the top of the piston, which has a mass of 225 lbm and a face area of 1 ft^2 . The mass of N_2 is 1.5 lbm and initially Nitrogen gas occupies a volume of 0.0045 m^3 . The volume of Nitrogen gas slowly decreases to 1 liter as energy with a magnitude of 2.4 kJ is slowly removed by heat transfer. The piston-cylinder material is a ceramic composite and thus a good insulator. Friction between the piston and cylinder wall can be ignored, and the local acceleration of gravity is $g = 32.0 \text{ ft/s}^2$. Nitrogen gas is considered to be the system

- Determine the work done by the Nitrogen gas in Btu
- Determine the change in specific internal energy of the Nitrogen gas, in Btu/lbm.

Problem 2 (30 points)

Steam enters a turbine operating at steady state at 2 MPa , 350°C with a velocity of 100 m/s . Saturated vapor exits at 0.1 MPa and a velocity of 50 m/s . The elevation of the inlet is 3 m higher than at the exit. The mass flow rate of the steam is 15 kg/s , and the power developed is 7 MW . Let $g = 9.81 \text{ m/s}^2$.

Inlet specific enthalpy = 3138.6 kJ/kg
Inlet specific volume = $0.1386 \text{ m}^3/\text{kg}$

Outlet specific enthalpy = 417.511 kJ/kg
Outlet specific volume = $0.001043 \text{ m}^3/\text{kg}$

Determine:

- The area at the inlet, in m^2 ,
- The volumetric flow rate at the outlet, in cm^3/s , and
- The rate of heat transfer between the turbine and its surroundings, in $\text{lb}_f\text{-ft/h}$.

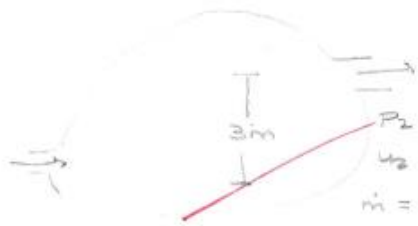
Problem 3 (20 points)

In the following, take $C_v = 35.4$ and $C_p = 44.5 \text{ Jmol}^{-1}\text{C}^{-1}$ for carbon disulfide (CS_2) gas: 264 g of carbon disulfide at 300°C is contained in a piston/cylinder arrangement. How much heat must be extracted from this system, which is kept at constant pressure, to cool it to 50°C if the heat capacity of the piston and cylinder is neglected?

$C=12$, $S=32$.

2.

Given



$$P_2 = 2 \text{ MPa}$$

$$T_2 = 350^\circ\text{C}$$

$$u_1 = 50 \text{ m/s}$$

$$h_1 = 3138.6 \text{ kJ/kg}$$

$$v_1 = 0.1386 \text{ m}^3/\text{kg}$$

$$W_2 = 7 \text{ MW}$$

Formulate

$$\rho = \frac{1}{v}, \quad \dot{m} = \rho u A, \quad \frac{d(mu)_{cv}}{dt} = - \left[(h_2 - h_1) + \left(\frac{u_2^2}{2} - \frac{u_1^2}{2} \right) + g(z_2 - z_1) \right] \dot{m} + \dot{Q} + \dot{W}_s$$

$$q = uA$$

Solve

$$a) \dot{m} = \rho u A \quad \frac{\text{kg}}{\text{m}^3 \text{s}}$$

$$15 \text{ kg/s} = \frac{1}{0.1386 \text{ m}^3/\text{kg}} (50 \text{ m/s}) (A) \rightarrow 15 = 721.5 A$$

$$A = 0.021 \text{ m}^2$$

$$b) q = uA$$

$$\dot{m} = \rho q \rightarrow 15 \text{ kg/s} = \frac{1}{0.001043 \text{ m}^3/\text{kg}} q \rightarrow 15 (0.001043) = q$$

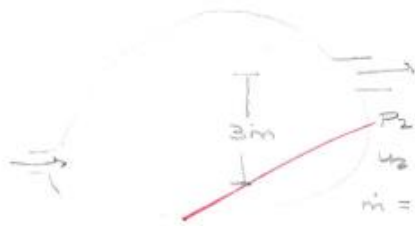
$$q = 0.0156 \text{ m}^3/\text{s}$$

$$\frac{0.0156 \text{ m}^3}{\text{s}} \times \frac{100^3 \text{ cm}^3}{1 \text{ m}^3} = 15600 \text{ cm}^3/\text{s}$$

$$q = 15600 \text{ cm}^3/\text{s}$$

2.

Given



$$P_2 = 2 \text{ MPa}$$

$$T_2 = 350^\circ\text{C}$$

$$u_1 = 50 \text{ m/s}$$

$$h_1 = 3138.6 \text{ kJ/kg}$$

$$v_1 = 0.1386 \text{ m}^3/\text{kg}$$

$$W_2 = 7 \text{ MW}$$

Formulate

$$\rho = \frac{1}{v}, \quad \dot{m} = \rho u A, \quad \frac{d(mu)_{cv}}{dt} = - \left[(h_2 - h_1) + \left(\frac{u_2^2}{2} - \frac{u_1^2}{2} \right) + g(z_2 - z_1) \right] \dot{m} + \dot{Q} + \dot{W}_s$$

$$q = uA$$

Solve

$$a) \dot{m} = \rho u A \quad \frac{\text{kg}}{\text{m}^3 \text{ s}}$$

$$15 \text{ kg/s} = \frac{1}{0.1386 \text{ m}^3/\text{kg}} (50 \text{ m/s}) (A) \rightarrow 15 = 721.5 A$$

$$A = 0.021 \text{ m}^2$$

$$b) q = uA$$

$$\dot{m} = \rho q \rightarrow 15 \text{ kg/s} = \frac{1}{0.001043 \text{ m}^3/\text{kg}} q \rightarrow 15 (0.001043) = q$$

$$q = 0.0156 \text{ m}^3/\text{s}$$

$$\frac{0.0156 \text{ m}^3}{\text{s}} \times \frac{100^3 \text{ cm}^3}{1 \text{ m}^3} = 15600 \text{ cm}^3/\text{s}$$

$$q = 15600 \text{ cm}^3/\text{s}$$

3. Given

$$C_v = 35.4 \text{ J mol}^{-1} \text{ } ^\circ\text{C}^{-1}$$

$$C_p = 44.5 \text{ J mol}^{-1} \text{ } ^\circ\text{C}^{-1}$$

$$m \text{CS}_2 = 264 \text{ g}$$

$$\Delta T = 50 - 300^\circ\text{C} = -250^\circ\text{C}$$

$$n \text{ moles} = \frac{m}{\text{MM}}$$

Formulate

$$n = \frac{m}{\text{MM}}, \Delta H = C_p \Delta T = Q$$

Solve

$$\text{MM CS}_2 = 12 + 32(2) = 76$$

$$n = \frac{264 \text{ g}}{76 \text{ g/mol}} = 3.47 \text{ mol}$$

$$Q = 3.47 \text{ mol} (44.5 \text{ J mol}^{-1} \text{ } ^\circ\text{C}^{-1}) (-250^\circ\text{C})$$
$$= -38603.75 \text{ J}$$

$$= 38603.75 \text{ J of heat must be extracted}$$

$$c) \frac{d(mu)_{av}}{dt} = - \left[(H_2 - H_1) + \left(\frac{u_2^2}{2} - \frac{u_1^2}{2} \right) + g(z_2 - z_1) \right] \dot{m} + \dot{Q} + \dot{W}_s$$

$$0 = - \left[(417.511 - 3138.6 \text{ kJ/kg}) + \left(\frac{50^2}{2} - \frac{100^2}{2} \right) \frac{\text{m}^2/\text{s}^2}{\text{m}^2/\text{s}^2} + 9.81(-3) \right] 15 \text{ kg/s} + \dot{Q} + 7 \text{ MW}$$

$$- [(-2721.09) + (-3750) \frac{\text{kJ/kg}}{\text{m}^2/\text{s}^2} + (-29.43) \frac{\text{kJ/kg}}{\text{m}^2/\text{s}^2}]$$

$$- [(-2721.09 + (-3.75) + (-0.2943)) \text{ kJ/kg}] 15 \text{ kg/s} + \dot{Q} + \dot{W}_s$$

$$- [(-2725.34 \text{ kJ/kg}) \times 15 \text{ kg/s}] + \dot{Q} + \dot{W}_s$$

$$[40880.09 \text{ kJ/s}] + 7 \times 10^6 \text{ W} + \dot{Q}$$

$$\frac{7 \times 10^6 \text{ W}}{1.355 \text{ W}} \left| \frac{1 \text{ lb ft/s}}{1.355 \text{ W}} \right| = 5166051.661 \text{ lb ft/s}$$

$$\frac{40880.09 \text{ kJ/s}}{1} \left| \frac{1000 \text{ J}}{1 \text{ kJ}} \right| = 40880090 \text{ J/s} = 40880090 \text{ W}$$

$$\frac{40880090 \text{ W}}{1.355 \text{ W}} \left| \frac{1 \text{ lb ft/s}}{1.355 \text{ W}} \right| = 30169808.12 \text{ lb ft/s}$$

$$30169808.12 + 5166051.661 = 35335859.78 \text{ lb ft/s}$$

$$\frac{35335859.78 \text{ lb ft}}{1} \left| \frac{3600 \text{ s}}{1 \text{ hr}} \right| = 1.272 \times 10^{12} \text{ lb ft/hr}$$

$$\dot{Q} = - 1.272 \times 10^{12} \text{ lb ft/hr}$$

Prairie View A & M University, CHEG 2334: Chemical Engineering Thermodynamics I Fall 2021: Mid-Term Exam, Wednesday, October 20, 2021. Instructor: Dr. Kazeem Olanrewaju

Closed Books

Name of Student: FAVOR LOUIS

	Terms (A)	Concept (B)	Answer
1	Isotherms	The units of force in American Engineering System (AES) of units is :	16
2	Internal energy	A mathematical model that relates pressure, temperature and volume is called	8
3	zero	In a constant pressure closed process, quantity of energy transfer as heat is equal to change in	14
4	Continuity equation	In energy balance, the difference between enthalpy and flow work is describe by a term called	24
5	Length	An example of a control volume that includes shaft work in its energy balance	21
6	Frictionless	An example of a supercritical fluid is	20
7	Dimensions	The mass balance for an open system is describe by :	4
8	Equation of state	$\left(\frac{\partial U}{\partial T}\right)$ is a mathematical model for depicting the specific heat capacity of what type of closed process	13
9	Gibbs Phase Rule	An increase in the energy of the system will result in a corresponding decrease in the energy of the	15
10	Boundary	The conditions of the mass within the control volume and at the boundary do not vary with time. The process is said to be at	22
11	Turbine	An extensive property is transform into intensive by dividing the value of the property with	14
12	Steady state	macroscopic characteristic of a system such as mass, volume, energy, pressure, and temperature of the system	28
13	Constant volume	Heat transfer into the control volume of an open system is	21
14	Enthalpy	The real or imaginary surface that separates the system from its surroundings	20
15	Environment	All additive terms on both sides of the equation must have the same	7
16	Pound force	The thermodynamic concepts responsible for determining the number of properties needed to fix a thermodynamic system	9
17	Positive	One of the features of a reversible process is that it is	6
18	Property	The change in internal energy of a reversible process is	3
19	Amount	What is the property by which temperature is calibrated in thermometer	5
20	Air	The line of proportionality between pressure and volume of fluid as depicted on a PV-phase diagram is describe as	1

AVERAGE

Average Student Original Graded Assignment

Prairie View A & M University, CHEG 2334: Chemical Engineering Thermodynamics I Fall
2021: Mid-Term Exam, Monday, October 20, 2021. Instructor: Dr. Kazeem Olanrewaju

You should not reference to or have access to your class notes, laptop, tablet, cell phone, smart phone, and any other electronic gadgets. Open Book

Name of Student: Breanna Nicholas

40
80

Problem 1 (30 points)

Nitrogen gas (N_2) is confined in a cylinder by a piston, and the atmosphere exerts a pressure of 14.7 lbf/in^2 on the top of the piston, which has a mass of 225 lbm and a face area of 1 ft^2 . The mass of N_2 is 1.5 lbm and initially Nitrogen gas occupies a volume of 0.0045 m^3 . The volume of Nitrogen gas slowly decreases to 1 liter as energy with a magnitude of 2.4 kJ is slowly removed by heat transfer. The piston-cylinder material is a ceramic composite and thus a good insulator. Friction between the piston and cylinder wall can be ignored, and the local acceleration of gravity is $g = 32.0 \text{ ft/s}^2$. Nitrogen gas is consider to be the system

- Determine the work done by the Nitrogen gas in Btu
- Determine the change in specific internal energy of the Nitrogen gas, in Btu/lbm.

Problem 2 (30 points)

Steam enters a turbine operating at steady state at 2 MPa, 350°C with a velocity of 100 m/s. saturated vapor exits at 0.1 MPa and a velocity of 50 m/s. The elevation of the inlet is 3 m higher than at the exit. The mass flow rate of the steam is 15 kg/s, and the power developed is 7 MW. Let $g = 9.81 \text{ m/s}^2$.

Inlet specific enthalpy = 3138.6 kJ/kg
Inlet specific volume = $0.1386 \text{ m}^3/\text{kg}$

Outlet specific enthalpy = 417.511 kJ/kg
Outlet specific volume = $0.001043 \text{ m}^3/\text{kg}$

Determine:

- The area at the inlet, in m^2 ,
- The volumetric flow rate at the outlet, in cm^3/s , and
- The rate of heat transfer between the turbine and its surroundings, in $\text{lb}_f\text{-ft/h}$.

Problem 3 (20 points)

In the following, take $C_v = 35.4$ and $C_p = 44.5 \text{ Jmol}^{-1}\text{C}^{-1}$ for carbon disulfide (CS_2) gas: 264 g of carbon disulfide at 300°C is contained in a piston/cylinder arrangement. How much heat must be extracted from this system, which is kept at constant pressure, to cool it to 50°C if the heat capacity of the piston and cylinder is neglected?

$C=12$, $S=32$.

Problem 1

given:

$$P_A = 14.7 \text{ lbf/in}^2 \quad M_P = 225 \text{ lbm} \quad A = 1 \text{ ft}^2 \quad M_g = 1.5 \text{ lbm}$$

$$V_1 = .0045 \text{ m}^3$$

$$V_2 = 1 \text{ L} = .001 \text{ m}^3 \quad g = 32.0 \text{ ft/s}^2$$

formulate:

$$P_g = P_A + P_P$$

$$P_P = F_P / A$$

$$F_P = \frac{1}{g_c} m g$$

$$F_P = 1 \text{ lbf} / 32.174 \text{ lbm} \cdot \text{ft/s}^2 (225 \text{ lbm}) (32 \text{ ft/s}^2)$$

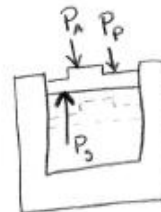
$$F_P = 223.78 \text{ lbf}$$

$$P_P = \frac{223.78 \text{ lbf}}{1 \text{ ft}^2} \cdot \frac{1 \text{ ft}^2}{144 \text{ in}^2} = 1.55 \text{ lbf/in}^2$$

$$P_g = 14.7 \text{ lbf/in}^2 + 1.55 \text{ lbf/in}^2 = 16.25 \text{ lbf/in}^2$$

$$W = -P \Delta V = -16.25 \text{ lbf/in}^2 \cdot (.0035 \text{ m}^3) =$$

$$\Delta u = Q + W$$



Problem 2

given:

$$H_1 = 3138.6 \text{ kJ/kg}$$

$$H_2 = 417.511 \text{ kJ/kg}$$

$$u_1 = .1386 \text{ m}^3/\text{kg}$$

$$u_2 = .001043 \text{ m}^3/\text{kg}$$

$$g = 32 \text{ ft/s}^2 = 9.81 \text{ m/s}^2$$

$$V_1 = 100 \text{ m/s}$$

$$V_2 = 50 \text{ m/s}$$

$$V = \dot{Q}/A$$

$$A = \dot{Q}/V$$

$$\text{accumulation} = \text{inlet} - \text{outlet} + \text{generation} - \text{consumption}$$

formulate: 0

$$\frac{d(mU)_{cv}}{dt} = - \left[\left((H_2 - H_1) + \left(\frac{u_2^2}{2} - \frac{u_1^2}{2} \right) + g(z_2 - z_1) \right) \dot{m} \right] + \dot{Q} + \dot{W}_s$$

$$- \left[\left((417.511 - 3138.6) + \left(\frac{.001043^2}{2} - \frac{.1386^2}{2} \right) + 9.81 \right) \dot{m} \right] + \dot{Q} + \dot{W}_s$$

$$- \left[\left((-2721.09 \frac{\text{kJ}}{\text{kg}}) + (.0096 \frac{\text{m}^3}{\text{kg}}) + 9.81 \text{ m/s}^2 \right) \dot{m} \right] + \dot{Q} + \dot{W}_s$$

Problem 3

given: $C_v = 35.4$ $C_p = 44.5 \text{ Jmol}^{-1} \text{ } ^\circ\text{C}^{-1}$ $(5) C = 12$ $S = 32$ $CS_2 = 264 \text{ g}$
 $T_1 = 300^\circ\text{C}$ $T_2 = 50^\circ\text{C}$

formulate:

$$\Delta H = C_p \Delta T = Q \quad (3) + 1$$

$$\Delta H = (44.5 \text{ Jmol}^{-1} \text{ } ^\circ\text{C}^{-1})(-250^\circ\text{C}) \quad (3) + 1$$

$$\Delta H = -11125 \text{ Jmol}^{-1} \text{ } ^\circ\text{C}^{-1} \quad (3)$$

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Closed Books

Name of Student: Breanna Nicholas

	Terms (A)	Concept (B)	Answer
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5	Length	An example of a control volume that includes shaft work in its energy balance	11
6	Frictionless	An example of a supercritical fluid is	20
7	Dimensions	The mass balance for an open system is describe by :	4
8	Equation of state	$\frac{\partial U}{\partial T}$ is a mathematical model for depicting the specific heat capacity of what type of closed process	19
9	Gibbs Phase Rule	An increase in the energy of the system will result in a corresponding decrease in the energy of the	15
10	Boundary	The conditions of the mass within the control volume and at the boundary do not vary with time. The process is said to be at	12
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14	Enthalpy	The real or imaginary surface that separates the system from its surroundings	10
15	Environment	All additive terms on both sides of the equation must have the same	7
16	Pound force	The thermodynamic concepts responsible for determining the number of properties needed to fix a thermodynamic system	9
17	Positive	One of the features of a reversible process is that it is	16
18	Property	The change in internal energy of a reversible process is	3
19	Amount	What is the property by which temperature is calibrated in thermometer	5
20	Air	The line of proportionality between pressure and volume of fluid as depicted on a PV-phase diagram is describe as	1

BELOW AVERAGE

Below Average Student Original Graded Assignment

Prairie View A & M University, CHEG 2334: Chemical Engineering Thermodynamics I Fall
2021: Mid-Term Exam, Monday, October 20, 2021. Instructor: Dr. Kazeem Olanrewaju

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Name of Student: Tijana Days

38
80

Problem 1 (30 points)

Nitrogen gas (N_2) is confined in a cylinder by a piston, and the atmosphere exerts a pressure of 14.7 lbf/in^2 on the top of the piston, which has a mass of 225 lbm and a face area of 1 ft^2 . The mass of N_2 is 1.5 lbm and initially Nitrogen gas occupies a volume of 0.0045 m^3 . The volume of Nitrogen gas slowly decreases to 1 liter as energy with a magnitude of 2.4 kJ is slowly removed by heat transfer. The piston-cylinder material is a ceramic composite and thus a good insulator. Friction between the piston and cylinder wall can be ignored, and the local acceleration of gravity is $g = 32.0 \text{ ft/s}^2$. Nitrogen gas is considered to be the system

- Determine the work done by the Nitrogen gas in Btu
- Determine the change in specific internal energy of the Nitrogen gas, in Btu/lbm.

Problem 2 (30 points)

Steam enters a turbine operating at steady state at 2 MPa , 350°C with a velocity of 100 m/s . Saturated vapor exits at 0.1 MPa and a velocity of 50 m/s . The elevation of the inlet is 3 m higher than at the exit. The mass flow rate of the steam is 15 kg/s , and the power developed is 7 MW . Let $g = 9.81 \text{ m/s}^2$.

Inlet specific enthalpy = 3138.6 kJ/kg
Inlet specific volume = $0.1386 \text{ m}^3/\text{kg}$

Outlet specific enthalpy = 417.511 kJ/kg
Outlet specific volume = $0.001043 \text{ m}^3/\text{kg}$

Determine:

- The area at the inlet, in m^2 ,
- The volumetric flow rate at the outlet, in cm^3/s , and
- The rate of heat transfer between the turbine and its surroundings, in $\text{lb}_f\text{-ft/h}$.

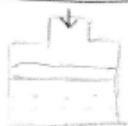
Problem 3 (20 points)

In the following, take $C_v = 35.4$ and $C_p = 44.5 \text{ J mol}^{-1}\text{ }^\circ\text{C}^{-1}$ for carbon disulfide (CS_2) gas. 264 g of carbon disulfide at 300°C is contained in a piston/cylinder arrangement. How much heat must be extracted from this system, which is kept at constant pressure, to cool it to 50°C if the heat capacity of the piston and cylinder is neglected?

$C=12$, $S=32$.

Tyana Days

Problem #1:



$$P_{\text{atm}} = 14.7 \text{ lbf/in}^2$$

$$W = -P \Delta V$$

$$P_P = \frac{F}{A}$$

$$P = P_{\text{atm}} + P_P$$

$$M = 225 \text{ lbm}$$

$$A = 9 \text{ ft}^2$$

$$M_g = 1.5 \text{ lbm}$$

$$g = 32.0 \text{ ft/s}^2$$

$$F = \frac{1}{g_c} M \cdot g$$

$$\frac{1}{g_c} = \frac{1 \text{ lbf}}{32.174 \text{ lbm ft/s}^2}$$

$$P_P = \frac{mg}{A}$$

$$\text{lbf} = 32.174 \text{ lbm ft/s}^2$$

$$P_P = \frac{(1.5 \text{ lbm})(32.0 \text{ ft/s}^2)}{(1 \text{ ft}^2)} = 48 \text{ lbm/ft}^2$$

$$P = (14.7 \text{ lbf/in}^2) + (48 \text{ lbm/ft}^2) = 62.7$$

$$\frac{1}{g_c} = \frac{1 \text{ lbf}}{32.174 \text{ lbm ft/s}^2} = 4.4482 \text{ N}$$

$$F = (4.4482 \text{ N})(225 \text{ lbm})(32.0 \text{ ft/s}^2) \frac{1}{g_c} = 1?$$

$$F = (1)(225 \text{ lbm})(32.0 \text{ ft/s}^2)$$

$$F = 7200 \text{ lbm ft/s}^2 = 223.7832 \text{ lbf}$$

$$V_1 = 0.0045 \text{ m}^3$$

$$V_2 =$$

Problem #2:

$$P_1 = 3138.6 \text{ kJ/kg}$$

$$V_1 = 0.1386 \text{ m}^3/\text{kg}$$

$$P_0 = 417.511 \text{ kJ/kg}$$

$$V_0 = 0.0010409 \text{ m}^3/\text{kg}$$

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

$$\text{Velocity} = 100 \text{ m/s}$$

$$\frac{d(mU)_{\text{cv}}}{dt} = - \left[(H_2 - H_1) + \left(\frac{U_2^2}{2} - \frac{U_1^2}{2} \right) + g(Z_2 - Z_1) \right] m + Q + W$$

$$A = \frac{\pi D^2}{4}$$

$$m = \rho U A$$

$$\gamma = \frac{mW}{10^6 W}$$

Problem #3

$$C = 12$$

$$S = 32$$

$$C_V = 35.4$$

$$C_P = 74.5 \text{ J/mol}^\circ\text{C}$$

$$W_2 = 264 \text{ g}$$

$$\Delta H = C_P \Delta T = Q$$

$$\Delta U = Q - W$$

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Closed Books

Name of Student: Tyana Days

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16	Pound-force	The thermodynamic concepts responsible for determining the number of properties needed to fix a thermodynamic system	9
17	Positive	One of the features of a reversible process is that it is	6
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19	Amount	What is the property by which temperature is calibrated in thermometer	3
20	Air	The line of proportionality between pressure and volume of fluid as depicted on a PV-phase diagram is describe as	1

**CHEMICAL ENGINEERING THERMODYNAMICS I SEMESTER
PROJECT
FALL 2021**

PROJECT TITLE: Matlab Project

TOPICS COVERED IN PROJRCT

Project covered the following topics:

1. Virial Equations of State
2. The Ideal Gas
3. Application of the Virial Equations
4. Cubic Equations of State
5. Generalized Correlations for Gases

CHEMICAL ENGINEERING THERMODYNAMICS I
SEMESTER PROJECT
FALL 2021

DETAILED PROJECT PROBLEM STATEMENT
AND REQUIREMENTS
CHEG 2334: THERMODYNAMICS I

MATLAB PROJECT (Due Date: 11/23/2021)

Prototype A

PROBLEM STATEMENT

Use MATLAB to Calculate Z and V for Ethane at 50 °C and 15 bar by the following equations:

- a) The truncated virial equation with the following experimental values of virial coefficients:
 $B = -156.7 \text{ cm}^3 \text{ mol}^{-1}$; $C = 9650 \text{ cm}^6 \text{ mol}^{-2}$
- b) The truncated virial equation, with a value of B from the generalized Pitzer correlation.
- c) The Redlich/Kwong equation
- d) The Soave/Redlich/Kwong equation
- e) The Peng/Robinson equation.

Deliverables

- 1) Write a MATLAB code to solve for Z and V in the problem statement
- 2) Use Excel Spreadsheet to solve for Z and V in the problem statement
- 3) Calculate Z and V from Generalized Compressibility factor Chart
- 4) Obtain the value of V from the Thermodynamic Properties of Species in the Problem Statement and use the V obtained to estimate your Z
- 5) Write a report on the values obtained from Thermodynamic Properties Table of the Species, Generalized Compressibility Chart, and all the Equations of State indicated under problem statement. Compare the values from these different methods (The method with most accurate values are the ones obtained from the Table).

Structure of the Report (4 pages)

- Introduction
- Methods (Source Code and Description of the different Method used)
- Result and Discussion
- Conclusion
- Reference

CHEMICAL ENGINEERING THERMODYNAMICS I FALL 2021

DETAILED PROJECT GRADING SCHEME

Structure of the Report (4 pages)

- Introduction : **15 points**
- Methods (Source Code and Description of the different Method used): **25 points**
- Result and Discussion: **30 points**
- Conclusion: **20 points**
- Reference: **10 points**

**ABOVE AVERAGE
PROJECT REPORT**

**Above Average Student/Group Original Graded Assignment
Including Rubric Showing Grading**

CHEG 2334 Project

Introduction:

To appropriately gauge the behavior of gases that are not acting ideal, it is necessary to calculate the compressibility factor (Z) of these real gases. It becomes possible to calculate this compressibility factor by using either the virial equation of state or the cubic equation of state. By following their respective parameters, both equations should result in the same compressibility factor. The cubic equation of state has a variety of forms including Relich/Kwong, Soave/Relich/Kwong, and Peng/Robinson. However, as long the correct parameters are used, there should be little to no variability in Z. In this project the task was to calculate the compressibility factor and volume of carbon monoxide, given temperature and pressure. This was done by utilizing the virial and cubic equations of state through the computational tools MATLAB, and Excel.

Method:

Truncated Virial Equation Using B and C:

% The goal of this project is to calculate V and Z

```
T=273+25;
P=10;
R=83.14;% unit of R is pa.cm^3/mol.K
% First we need to calculate V for ideal gas
% Ideal Equation is PV=RT
Vig=(R*T)/P;

% To solve for V for the Virial EOS
% Vv=(RT/P) ( 1+B/V + C/V^2)
B=-8.6;
C=1550;
% f=@(V) ((R*T)/P+(R*T*B)/(P*V)+(R*T*C)/(P*V^2))-V;

Vv=fzero(f(V) ((R*T)/P+(R*T*B)/(P*V)+(R*T*C)/(P*V^2))-V, Vig);
Zv=(R*T)/(Vv*P);
```

Name	Value
B	-8.6000
C	1550
P	10
R	83.1400
T	298
Vig	2.4776e+03
Vv	2.4696e+03
Zv	1.0032

Truncated Virial Equation Using the Pitzer Correlation:

```
% To solve for Z and V using Truncated Virial
% Z=1+ B0*P/T + B1*P/T^2 + w*B1*P/T^2
T=298;
P=10;
w=0.048;
Tc=132;
Pc=34.99;
R=83.14;
Tr=T/Tc;
Pr=P/Pc;

B0= 0.083-(0.422/Tr^1.6);
B1= 0.139-(0.172/Tr^4.2);
Zt=1 + B0*(Pr/Tr) + (w*B1*(Pr/Tr));
Vt=(Zt*R*T)/P;
```

Name	Value
B0	-0.0817
B1	0.1334
P	10
Pc	34.9900
Pr	0.2858
R	83.1400
T	298
Tc	132
Tr	2.2576
Vt	2.4696e+03
w	0.0480
Zt	0.9968

Part A		Part B	
Virial EOS	$V = (RT/P(1+B/V+C/V^2))$	T	298
Vf=Vi		P	10
V2=V1		w=0.048;	0.048
		Tc=132;	132
		Pc=34.99;	34.99
B	-8.6	R=83.14;	83.14
C	1550	Tr=T/Tc;	2.257575758
		Pr=P/Pc;	0.285795942
V	2469.573819	B0	-0.031679217
	-1.89834E-08	B1	0.133373599
Z	0.996771766	Z	0.996800043
		V	2469.643876

Relich/Kwong:

% To solve for E and V using Redlich/Kwong equation

```
%? = 1 + ?^0?_?/?_? + ??^1?_?/?_?
T=273+25;
P=10;%convert to bar
w=0.048;
Tc=132.9;
Pc=34.99;
R=83.14;
Tr=T/Tc;
Pr=P/Pc;
%Data obtain from Table 3.1 in the Power point slide from chapter 3
e=0;%eeta
c=1;%sigma
omega= 0.08664;
phi=0.42748;
B=(omega)*(Pr/Tr);
a=Tr^(1/2);
q=(phi*a)/(omega*Tr);
V=(R*T)/P;

% Redlich/Kwong Equation
%? = 1 + ??? (???) / (???) (???)
%2 = 1 + B - (q*B) * ((Z-B) / ((Z+(e*B)) * (Z+(c*B)))));

Zrk=fzero(@(Z) (1+B-(q*B)*((Z-B)/((Z+(e*B))*(Z+(c*B)))))-Z, 1)
Vrk=(Zrk*R*T)/P
```

Name	Value
a	0.6678
B	0.0110
c	1
e	0
omega	0.0866
P	10
Pc	34.9900
phi	0.4275
Pr	0.2858
q	1.4695
R	83.1400
T	298
Tc	132.9000
Tr	2.2423
V	2.4776e+03
Vrk	2.4654e+03
w	0.0480
Zrk	0.9951

Soave/Relich/Kwong:

% To solve for E and V using Soave/Redlich/Kwong equation

```
%? = 1 + ?^0?_?/?_? + ??^1?_?/?_?
T=273+25;
P=10;%convert to bar
w=0.048;
Tc=132.9;
Pc=34.99;
R=83.14;
Tr=T/Tc;
Pr=P/Pc;
%Data obtain from Table 3.1 in the Power point slide from chapter 3
e=0;%eeta
c=1;%sigma
omega= 0.08664;
phi=0.42748;
%a=Tr^(1/2);
a=(1+0.480+(1.574*w)-(0.176*w^2))*(1-Tr^(1/2))^2;
B=(omega)*(Pr/Tr);
q=(phi*a)/(omega*Tr);
```

Name	Value
a	2.4204
B	0.0110
c	1
e	0
omega	0.0866
P	10
Pc	34.9900
phi	0.4275
Pr	0.2858
q	5.3258
R	83.1400
T	298
Tc	132.9000
Tr	2.2423
V	2.4776e+03
Vsrk	2.3552e+03
w	0.0480
Zsrk	0.9506

$$V = (R \cdot T) / P;$$

```
% Redlich/Kwong Equation
%Z=1+???? (???) / (???) (???)
%Z=1+B-(q*B)*((Z-B)/((Z+(e*B))*(Z+(c*B)))));

Zsrk=fzero(@(Z) (1+B-(q*B)*((Z-B)/((Z+(e*B))*(Z+(c*B)))))-Z, 1)
Vsrk=(Zsrk*R*T)/P
```

Relich/Kwong:

T=273+25;	298
P=10;%convert to bar	10
w=0.048	0.048
Tc=132.9	132.9
Pc=34.99;	34.99
R=83.14;	83.14
Tr=T/Tc;	2.242287
Pr=P/Pc;	0.285796
e=0;%eeta	0
c=1;%sigma	1
omega=0.08664;	0.08664
phi=0.42748;	0.42748
%a=Tr^(1/2);	0.667812
a=(1+0.480+(1.574*w)-(0.176*w^2))*(1-Tr^(1/2))^2;	2.42037
B=(omega)*a*(Pr/Tr);	0.011043
q=(phi*a)/(omega*Tr);	1.469469
V=(R*T)/P;	2477.572
Z=1+B-(q*B)*((Z-B)/((Z+(e*B))*(Z+(c*B))));	0.99517
Guess value is Z is 1	1

Soave/Relich/Kwong:

T=273+25;	298
P=10;%convert to bar	10
w=0.048	0.048
Tc=132.9	132.9
Pc=34.99;	34.99
R=83.14;	83.14
Tr=T/Tc;	2.242287
Pr=P/Pc;	0.285796
e=0;%eeta	0
c=1;%sigma	1
omega=0.08664;	0.08664
phi=0.42748;	0.42748
a=(1+0.480+(1.574*w)-(0.176*w^2))*(1-Tr^(1/2))^2;	2.42037
a=(1+0.480+(1.574*w)-(0.176*w^2))*(1-Tr^(1/2))^2;	2.42037
B=(omega)*a*(Pr/Tr);	0.011043
q=(phi*a)/(omega*Tr);	5.325836
V=(R*T)/P;	2477.572
Z=1+B-(q*B)*((Z-B)/((Z+(e*B))*(Z+(c*B))));	0.993515
Guess value is Z is 1	1

Peng/Robinson:

```
% To solve for Z and V using The Peng/Robinson Equation
% Z=1+β-qβ (Z-β)/(Z+εβ)(Z+σβ)
% β=0 Pr/Tr
% q=Ψ(Tr;ω)/(ΩTr)
% α α_PR (T_r;ω)=[1+(0.37464+1.54226ω-0.26992ω^2)(1-Tr^(1/2))]^2
```

```
T=298;
P=10;
Tc=132.9;
Pc=34.99;
O=0.07780; % omega
Pr=P/Pc;
Tr=T/Tc;
B=0*(Pr/Tr); % beta
W=0.45724; % phi
S=1+sqrt(2); % sigma
E=1-sqrt(2); % epsilon
R=83.14;
```

```
A=(1+(0.37464+1.54226*(W)-0.26992*(W^2))*(1-Tr^(1/2)))^2;
Q=(W*A)/(O*Tr);
%Z=1+B-(Q*B)*((Z-B)/((Z+E*B)*(Z+S*B)));
Z=fzero(@(Z) (1+B-(Q*B)*((Z-B)/((Z+(E*B))*(Z+(S*B)))))-Z, 1);
%Zpr=fzero(@(Z) (1+B-(q*B)*((Z-B)/((Z+(e*B))*(Z+(c*B)))))-Z, 1)
```

$$V = (Z \cdot R \cdot T) / P;$$

Name	Value
A	0.2410
B	0.0099
E	-0.4142
O	0.0778
P	10
Pc	34.9900
Pr	0.2058
Q	0.6317
R	83.1400
S	2.4142
T	298
Tc	132.9000
Tr	2.2423
V	2.4871e+03
W	0.4572
Z	1.0039

T	298					
P	10					
Tc	132.9					
Pc	34.99					
O (omega)	0.0778					
B=O*(Pr/Tr)	0.009916179					
W (psi)	0.45724					
Sigma=1+sqrt(2)	2.414213562					
Epsilon=1-sqrt(2)	-0.41421356					
Tr=T/Tc	2.242287434					
Pr=P/Pc	0.285795942					
A=[1+(0.37464+1.54226*(W)-0.26992*(W^2))*(1-Tr^(1/2)))]^2					0.24102	
Q=(W*A)/(O*Tr)					0.631722	
Z=1+B-Q*B*((Z-B)/((Z+E*B)*(Z+S*B)))					1.003834	
1+C9-H18*C9*((Z-C9)/((Z+C12*C9)*(Z+C11*C9)))						
R	83.14					
Guess Value is Z is 1				1		
V=(Z*R*T)/P				2487.071		

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NIST Webbook (Thermodynamics Properties):

Fluid Data

Isothermal Data for T = 298.00 K

Temperature (K)	Pressure (bar)	Density (mol/l)	Volume (l/mol)	Internal Energy (kJ/mol)	Enthalpy (kJ/mol)	Entropy (J/mol*K)	Cv (J/mol*K)	Cp (J/mol*K)	Sound Spd. (m/s)	Joule-Thomson (K/bar)	Viscosity (uPa*s)	Therm. Cond. (W/m*K)	Phase
298.00	10.000	0.40492	2.4696	9.8514	12.321	92.778	20.894	29.652	353.21	0.24596	17.890	0.026625	vapor

Volume = 2469.6 cm³/mol

According to $Z = PV/RT = (10 \text{ bar} * 2469.6 \text{ cm}^3/\text{mol}) / (83.14 \text{ bar cm}^3/\text{mol K} * 298 \text{ K}) = 0.9968$

Generalized Compressibility Chart:

$Z \approx 1 \rightarrow$ According to $V = ZRT/P = (1 * 83.14 \text{ bar cm}^3/\text{mol K} * 298 \text{ K} / 10 \text{ bar}) = 2477.57 \text{ cm}^3/\text{mol}$

In order to find Z and V in MATLAB and Excel for the virial and cubic equations of state for carbon monoxide at P=10 bar and T=298K, it was necessary to name the variables such as B, C, B1 and B0 for the virial equation and omega, psi, beta, sigma, and epsilon for the cubic equation and solve for those values. After, V was solved for first for the virial equation using B and C, and Z was solved for without using iteration for the Pitzer correlation. The compressibility factor was solved for using the Relich/Kwong, Soave/Relich/Kwong, and Peng/Robinson equations by iteration. After finding either Z or V by iteration (shown by using the fvalue function in MATLAB and Data → Solver in Excel) the equation $Z = PV/RT$ was used to find the missing variable.

Results and Discussion:

% Error	B & C	Pitzer	RK	SRK	PR	GCC
Z	0.35	0	0.17	0	0.71	0.2
V	0	0	0.32	0.32	0.71	0.32

The results of the MATLAB and Excel functions as well as the Generalized Compressibility Chart yielded results that varied little from the NIST Web Book compressibility factor and volume. Overall, the using the percent error equation with the results shown in the table above, we are able to see that none of the different equations shifted away from the NIST Chemistry Web Book over one percent. This verifies that the equations are precise and accurate enough to calculate the behavior, general compressibility, and volume of real gases as they deviate from their ideal state.

Conclusion:

The results obtained from the virial and cubic equations and their variations are considerably more accurate when compared to the result gained from the NIST Chemistry Web Book. It is observed that there are very small differences between the values obtained from MATLAB and Excel and it is clear to say that based on these results these equations are precise and accurate. The results showed that the codes we had were able to be run on MATLAB worked. Also we were able to get calculations working in the Excel with the right equations. In conclusion, we we're able to use a multitude of equations as well as computation tools to result in the same value.

References:

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"Thermophysical Properties of Fluid Systems." *the NIST WebBook*, <https://webbook.nist.gov/chemistry/fluid/>. Accessed 1 December 2021.

**AVERAGE
PROJECT REPORT**

**Average Student/Group Original Graded Assignment
Including Rubric Showing Grading**

CHEG 2334: THERMODYNAMICS I

MATLAB PROJECT

PROTOTYPE C

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AKILI TODMAN

TYANA DAYS

85/100

The goal of this project is to calculate the values Z (compressibility factor) and V (Volume) under the following conditions: Temperature $T = 250$ C and Pressure $P = 1800$ kPa ; using 5 different methods:

- A) The truncated Virial Equation with coefficients $B = -152. \text{cm}^3 \text{mol}^{-1}$ and $C = -5800 \text{cm}^6 \text{mol}^{-2}$.
- B) The truncated virial equation with a value of B from Generalized Pitzer correlation.
- C) The Redlich /Kwong equation .
- D) The Soave /Redlich/Kwong equation.
- E) The Peng/Robinson equation.

For the purpose of this project, Matlab and Excel will be the two major tools used.

First, we used Matlab to calculate the values of Z and V using the five equations mentioned above. See below the codes and the answers we came up with:

SOLUTION TO Question a for Prototype C

%The goal of this project is to calculate V and Z

$T=523$

$P=18$

$R=83.14$; % unit of R is $\text{pa.cm}^3/\text{mol.K}$

%First we need to calculate V for ideal gas

%Ideal equation is $PV=RT$

$V_{ig} = (R \cdot T)/P$

% To solve for V for the Virial EOS

$V_v = (RT/P) \left((1+B)/V + C/V^2 \right)$

$B=-152.5$;

$C=-5800$;

$\%f=@(V) ((R \cdot T)/P + (R \cdot T \cdot B)/(P \cdot V) + (R \cdot T \cdot C)/(P \cdot V^2)) - V$

$\%f=@(V) ((R \cdot T)/P + (R \cdot T \cdot B)/(P \cdot V) + (R \cdot T \cdot C)/(P \cdot V^2)) - V$

```

Vv=fzero(@(V) ((R*T)/P+(R*T*B)/(P*V)+(R*T*C)/(P*V^2))-V,Vig)
Z=(P*Vv)/(R*T)
ANSWERS: V = 2.4157e+03 cm³ / mol
Vv= 2.249e+03 cm³ / mol
Z = 0.9310

```

SOLUTION to Question b for Prototype C

% To solve for Z and V using Truncated Virial

```

%?=1+ ?^0?_?/?_? +??^1?_?/?_?

```

```

T=523;

```

```

P=18 ;

```

```

w=0.345;

```

```

Tc=647.1;

```

```

Pc=220.55;

```

```

R=83.14;

```

```

Tr=T/Tc;

```

```

Pr=P/Pc;

```

```

B0= 0.083-(0.422/Tr^1.6);

```

```

B1= 0.139-(0.172/Tr^4.2);

```

```

Z=1 + B0*(Pr/Tr)+ (w*B1*(Pr/Tr))

```

```

V=(Z*R*T)/P

```

```

ANSWERS: V = 2.2675e+03 cm³ / mol

```

```

Z = 0.9387

```

SOLUTION to Question c for Prototype C

% To solve for Z and V using the Redlich/Kwong

```

equation %?=1+ ?^0?_?/?_? +??^1?_?/?_?

```

```

T=523;

```

```

P=18;%convert to bar

```

```

w=0.345;

```

```

Tc=647.1;

```

```

Pc=220.55;

```

```

R=83.14;

```

```

Tr=T/Tc;

```

```

Pr=P/Pc;

```

```

%Data obtain from Table 3.1 in the Power point slide from chapter 3

```

```

e=0;%eeta

```

```

c=1; %sigma

```

```

omega= 0.08664;

```

```

phi=0.42748;

```

```

B=(omega)*(Pr/Tr);
a=Tr^(1/2);
q=(phi*a)/(omega*Tr);
V=(R*T)/P
% Redlich/Kwong Equation
%?=1+???? (???)/(?+??)(?+??)
Zrk=fzero(@(Z) (1+B-(q*B)*((Z-B)/((Z+(e*B))*(Z+(c*B))))))-Z, 1)
Vrk=(Zrk*R*T)/P
ANSWERS:
Zrk = 0.9472
Vrk= 2.2881e+03 cm³/ mol

```

SOLUTION to Question d for Prototype C

```

% To solve for Z and V using Soave/Redlich/Kwong equation
%?=1+ ?^0?_/?_? +??^1?_/?_?
T=523;
P=18;%convert to bar
w=0.345;
Tc=647.1;
Pc=220.55;
R=83.14;
Tr=T/Tc;
Pr=P/Pc;
%Data obtain from Table 3.1 in the Powerpoint slide from chapter 3
e=0;%eeeta
c=1; %sigma
omega= 0.08664;
phi=0.42748;
B=(omega)*(Pr/Tr);
a=(1+(0.480+ 1.574*omega-0.176*omega^2)*(1- (Tr^(1/2))))^2);
q=(phi*a)/(omega*Tr);
V=(R*T)/P
% Soave/Redlich/Kwong Equation
%?=1+???? (???)/(?+??)(?+??)
Zsrk=fzero(@(Z) (1+B-(q*B)*((Z-B)/((Z+(e*B))*(Z+(c*B))))))-Z, 1)
Vsrk=(Zsrk*R*T)/P
ANSWERS:
Vsrk= 2.3029e+03 cm³/ mol
Zsrk = 0.9533

```

SOLUTION to Question e for Prototype C

% To solve for Z and V using Peng/ Robinson equation

$\phi^s = 1 + \frac{a}{RT} \left(\frac{1}{Z} - 1 \right) + \frac{b}{RT} \ln \phi^s$

T=523;

P=18;%convert to bar

w=0.345;

Tc=647.1;

Pc=220.55;

R=83.14;

Tr=T/Tc;

Pr=P/Pc;

%Data obtain from Table 3.1 in the Powerpoint slide from chapter 3

e=1-2^{0.5};%eeta

c=1+2^{0.5};%sigma

omega= 0.07780;

phi=0.45724;

B=(omega)*(Pr/Tr);

a=(1+(0.37464+ 1.54226*omega-0.26992*omega²)*(1- (Tr^{1/2})))²);

q=(phi*a)/(omega*Tr);

V=(R*T)/P

% Peng / Robinson Equation

$\phi^s = 1 + \frac{a}{RT} \left(\frac{1}{Z} - 1 \right) + \frac{b}{RT} \ln \phi^s$

Zpr=fzero(@(Z) (1+B*(q*B)*((Z-B)/((Z+(e*B))*(Z+(c*B)))))-Z, 1)

Vpr=(Zpr*R*T)/P

ANSWERS:

Vpr= 2.2919e+03 cm³/ mol

Zpr = 0.9487

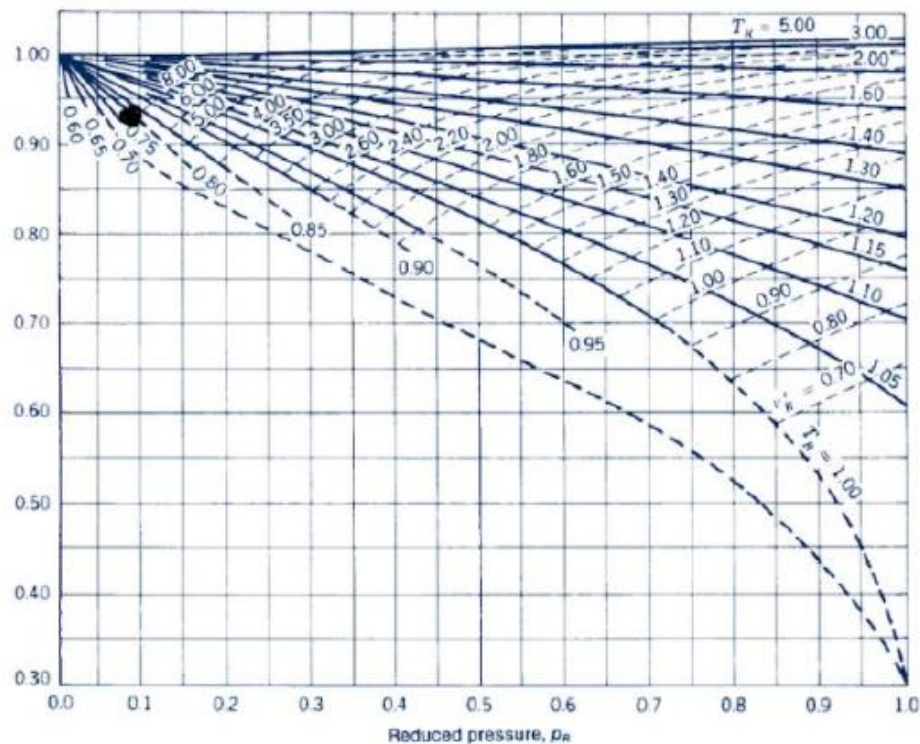
The second method used to calculate Z and V is Excel. Please refer to the attached Excel sheet provided.

Part b					
T	523				
P	18				
w	0.345				
Tc	647.1	part a			
Pc	220.55				
R=83.14;	83.14	Virial EOS $V=(RT/P(1+B/V+C/V^2))$			
Tr=T/Tc;	0.808221295	Vf=Vi			
Pr=P/Pc;	0.08161414645	V2=V1			
B0	-0.5102858473				
B1	-0.2816309578	B	-152.5		
Z	0.9386598777	C	-5800		
V	2267.50085	V	2469.573819		
			-1606.003561		
		Z	1.022310469		

P	18	P	18	P	18
w	0.345	w	0.345	w	0.345
Tc	647.1	Tc	647.1	Tc	647.1
Pc	220.55	Pc	220.55	Pc	220.55
R=83.14;	83.14	R=83.14;	83.14	R=83.14;	83.14
Tr=T/Tc;	0.808221295	Tr=T/Tc;	0.808221	Tr=T/Tc;	0.808221
Pr=P/Pc;	0.08161414645	Pr=P/Pc;	0.081614	Pr=P/Pc;	0.081614
e	0	e	0	e	-0.414211
c	1	c	1	c	2.414213
omega	0.08664	omega	0.08664	omega	0.08664
phi	0.42748	phi	0.42748	phi	0.42748
B	0.00874890292	B	0.008748	B	0.008748
a	0.8990112875	a	1.007761	a	1.006381
q	5.488228852	q	6.152119	q	6.143775
V	2415.678889	V	2415.67	V	2415.678
Random	0.96	Random	1	Random	1
Zrk	0.9596356099	Zrk	0.955858	Zpr	0.956380
Vrk	2318.371639	Vrk	2309.046	Vpr	2310.308

(25)

The third method used to calculate the values of Z and V entail using the Generalized Compressibility factor chart. We marked the around area where Z is based off of our calculations.



We got P_R by converting 1800kPa to 18bars then using the P_c founded on the table in the book 220.55 bars we found that $P_R = 18/220.55 = 0.0816$ and for T_R we converted 250C to 523K using the T_c for water in the book 647.1 we got $T_R = 523/647.1 = 0.8082$ using the compressibility chart Z will roughly be close to 0.9319.
And we know $V = (ZRT)/P$
Therefore, $V = (0.9319 \cdot 83.14 \cdot 523) / 18 = 2251.47 \text{ cm}^3/\text{mol}$

The fourth method used to calculate V and Z utilizes the Thermodynamic Properties table of Species. The following values were obtained from the tables:

Auxiliary Data

Reference States, default for fluid

Enthalpy	H = 45.957191 kJ/mol at 300.0 K and 0.010 bar.
Entropy	S = 164.005224 J/mol*K at 300.0 K and 0.010 bar.

Additional fluid properties

Critical temperature (T_c)	647.096 K
Critical pressure (P_c)	220.640 bar
Critical density (D_c)	17.873728 mol/l
Acentric factor	0.3443
Normal boiling point	373.1243 K
Dipole moment	1.855 Debye

Using these numbers, we can calculate $T_r = T/T_c$ and $P_r = P/P_c$ and then come up the values a and b to calculate V. Then we can calculate Z from V.

Equation

$$P = (RT/(V-b)) - a/V^2$$

$$V = 2279.81 \text{ cm}^3/\text{mol}$$

$$Z = (P \cdot V) / (RT) = 0.9311$$

Interpretation

We can observe from comparing the different results obtained that the values for Z and V are roughly the same for all methods used. However, the most accurate method is the fourth one, which utilizes the Thermodynamic Properties table of Species.

Introduction: The goal of this project was to solve for the virial equation given using various methods to solve it and to see which one is the most accurate. We used four methods to solve the equation. The first one we were required to use was Matlab. The second method was using Microsoft excel. The third method was solving the equation using the compressibility chart given to us in the project. Lastly using the thermodynamic properties found by going to the chemistry webbook.

Method: Each method provided good results. The Matlab took the longest amount of time but each was close but only of the codes lead to it being the closest towards the exact answer by inputting a code to solve the virial equations given to us. Next we used Excel to solve a formula which roughly matched the matlab we did by putting in the formula to solve in the excel and also input other numbers given from the appendix to help us solve the equation. We then used the compressibility chart by getting T_c and P_c to then get T_r and P_r then graph where our Z would be to then solve V , which roughly gave the same numbers as the previous methods. The final method we used thermodynamic properties to help us find Z and V which was the easiest to do since we just did simple calculations and put them in and had it solve it for us. I would say the method that works the best is Excel since the compressibility chart does not give you exact measurements so it isn't the best way to get data, the thermodynamics does not allow you to do other equations like Redlich/Kwong, and the Matlab takes forever to download and code.

Results/Discussion:

	Estimated Values	True Values	Percentage Error
V	2251.17	2279.81	1.26%
Z	0.9319	0.9311	-0.09%

In the table above we are comparing the estimated and true values of V and Z to formulate the percentage error. The percentage error was calculated by subtracting the estimated value from the true value, divided by the true value then multiplied by 100. The estimated values were within a very close range of the true value due to the accuracy of the data found with the multiple methods used throughout the project.

Conclusion: The method that was the most efficient in getting us an estimated value as close to the true values was in method 3. During method 3, we used the Generalized Compressibility factor chart where we were able to see the p - v - T relation for gases. The chart was a necessary tool to predict the properties of gases as well as mixtures with accuracy.

References

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**BELOW AVERAGE
PROJECT REPORT**

**Below Average Student/Group Original Graded Assignment
Including Rubric Showing Grading**

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MATLAB Mini Project Lab Report Prototype D

Introduction

Group 1 will be using MATLAB and other calculative resources to better understand Prototype D. Our Prototype has been identified as methane, a hydrocarbon. Methane contains 1 carbon and 4 hydrogen atoms (CH_4) and can sometimes also be known as "natural gas". We will be using the information given to provide the calculations of the V and Z for methane using the truncated virial equation, Redlich/Kwong equation, the Soave/Redlich/Kwong equation and the Peng/Robinson equation, to solve the non-ideal gas.

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Methods

MATLAB Source Code:

Matlab was used to calculate V and Z using different equations, we entered the values and equations into Matlab as depicted in the source code below. Matlab then calculated our true and estimated values of V and Z using the various equations..

```
% MatLab Mini Project Group 1 Prototype D
% The goal of this project is to calculate V and Z
T= 273; %Kelvin
P= 20; %Barr
R= 83.14; % pa.cm^3/mol.K

% Calculaye V for ideal gas
% Ideal Gas Equation PV=RT
Vig=(R*T)/P

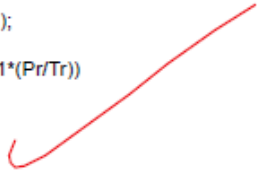
% To solve for V for the Virial EOS
% Vv=(RT/P)( 1+B/V + C/V^2)
B=-53.8;
C=2620;
%f=@(V) ((R*T)/P+(R*T*B)/(P*V)+(R*T*C)/(P*V^2))-V
Vv=fzero(@(V) ((R*T)/P+(R*T*B)/(P*V)+(R*T*C)/(P*V^2))-V,Vig)

% Part B: Solve for Z and V using Truncated Virial
T= 273;
P= 20;
w= 0.012;
Tc= 190.6;
Pc= 45.99;
```

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R= 83.14;
Tr= T/Tc;
Pr= P/Pc;
B0= 0.083-(0.422/Tr^{1.6});
B1= 0.139-(0.172/Tr^{4.2});
Zt=1 + B0*(Pr/Tr)+ (w*B1*(Pr/Tr))
Vt=(Z*R*T)/P



% Part C: Solve for Z and V using Redlich/Kwong equation

T= 273;
P= 20;
w= 0.012;
Tc= 190.6;
Pc= 45.99;
R= 83.14;
Tr= T/Tc;
Pr= P/Pc;



% Data obtained from Table 3.1 in the Powerpoint slide from chapter 3

e= 0; %eeta
c= 1; %sigma
omega= 0.08664;
phi=0.42748;
B=(omega)*(Pr/Tr);
a=Tr^{-1/2};
q=(phi*a)/(omega*Tr);
V=(R*T)/P;

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% Redlich/Kwong Equation

% $Z = 1 + B \cdot (q \cdot B) \cdot ((Z - B) / ((Z + (e \cdot B))^2 (Z + (c \cdot B))))$;

Zrk=fzero(@(Z) (1+B-(q*B)*((Z-B)/((Z+(e*B))^2*(Z+(c*B)))))-Z, 1)

Vrk=(Zrk*R*T)/P

Solutions :

Vig = 1.1349e+03

Vv = 1.0809e+03

Zt = 0.9535

Vt = 1.0820e+03

Zrk = 0.0211

Vrk = 23.9682

Excel:

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Another method used was excel, we entered the values and equations to compute values for V and Z.

T =	273		
P =	20		
R =	83.14		
Calculate V for Ideal			
Vig =	$=(B4*B2)/B3$		
Solve for V for Virial			
B =	-53.8		
C =	2620		
Vv =	$=((B4*B2)/B3+(B4*B2*B10)/(B3*B7)+(B4*B2*B11)/(B3*B7^2))-C7$		
Solve for Z and V using Truncated Virial			
w =	0.012		
Tc =	190.6		
Pc =	45.99		
Tr =	$=B2/B17$		
Pr =	$=B3/B18$		
B0 =	$=0.083-(0.422/B19^{1.6})$		
B1 =	$=0.139-(0.172/B19^{4.2})$		
Zt =	$=1+B21*(B20/B19)+(B15*B22*(B20/B19))$		
Vt =	$=(B24*B4*B2)/B3$		
Solve for Z and V using Redlich/Kwong equation			
e =	0		
c =	1		
omega =	0.08664		
phi =	0.42748		
B =	$=B30*(B20/B19)$		
a =	$=B19^{1/2}$		
q =	$=(B31*B33)/(B30*B19)$		
V =	$=(B4*B2)/B3$		
Zrk =	0.951		
Vrk =	$=(B37*B4*B2)/B3$		

Compressibility Chart:

We used the Compressibility Factor Chart by finding reduced pressure (p/p_c) and solving PV/RT to find Z for the compressibility factor, to finally graph the dot on the chart.

$$P_r = P/P_c$$

$$Z = PV/RT$$

$$P_r = 20/45.99$$

$$Z = 20 \cdot 1134.86 / 83.14 \cdot 273$$

$$P_r = 0.434877$$

$$Z = 1$$

Discussion / Results :

	V	Z	Percent Difference V
Ideal Gas	1134.861	-	-
Virial EOS	1083.37	-	4.54%
Truncated Virial	1082.046	0.953461	4.65%
Redlich/Kwong	1079.253	0.951	4.90%

The value of V was obtained using the ideal gas equations and this was used as our true value. Each of the following values for V were then compared to each other. They were precise but could have been more accurate. The percent difference for each of the equations was 4% or less.

Conclusion:

The virial EOS was the most accurate equation used to solve for V . The truncated virial and Redlich/Kwong equations are still precise, but are not the most accurate equations.

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