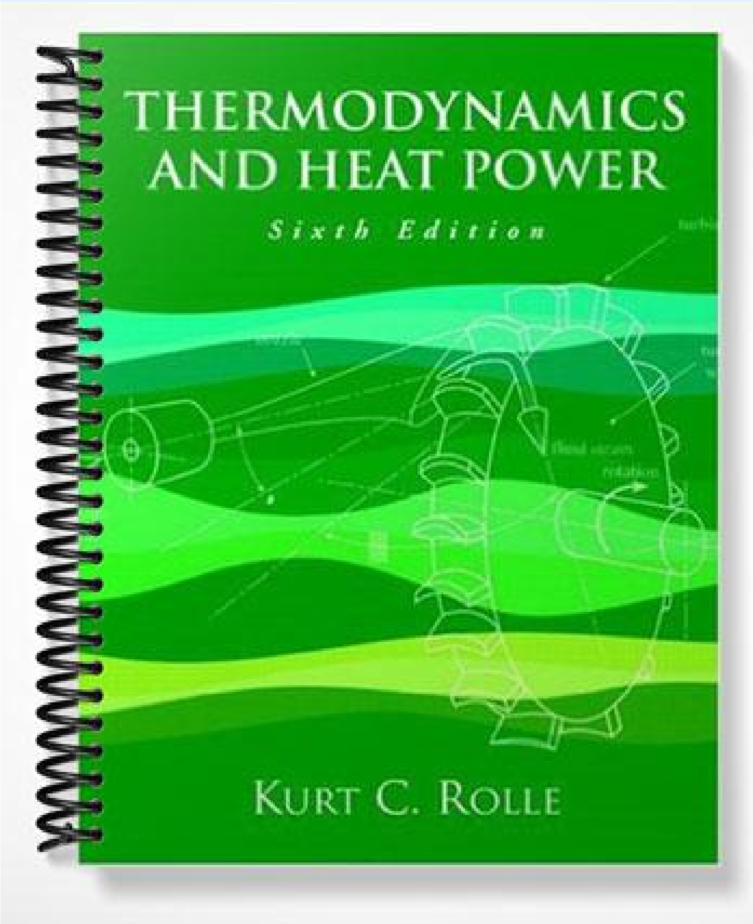
SOLUTIONS MANUAL



Instructor's Manual and Solutions Manual
to accompany

Thermodynamics and Heat Power

Sixth Edition

Kurt C. Rolle

PEARSON Prentice Hall

Upper Saddle River, New Jersey
Columbus, Ohio

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Hall

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This manual is intended to be an aid in using and studying from the textbook, *Thermodynamics and Heat Power, Sixth Edition,* by Kurt C. Rolle. There are included solutions to the practice problems at the end of each chapter and some brief suggested answers to the discussion questions. In addition, there are eleven suggested lesson plans for various courses and I am including an example syllabus of a course which I have offered in engineering from time to time.

The approaches to solving thermodynamic problems are often subject to various interpretations and assumptions, so more than one correct method may be used for the same problem. The methodology and solutions set down in this manual often include some discussion about the assumptions or observations that can help to clarify the methods. Calculations are shown in as complete a manner as possible and answers are indicated with an underline. Many of the problem solutions are quite lengthy and then some details are omitted. In those cases it is usual that other previous problem solutions demonstrate the same sort of detailed calculations. Also, some of the problems were solved using the computer with the software package of programs mentioned in the textbook and listed in the appendix A. In those instances, the solution set down in this manual often includes only the program inputs and the resulting outputs. Numerical answers are given to at least three significant figures or, in the case of irrational numerical answers, a series of dots (...) indicate that the answer has been left in an incomplete form. For example the value of pi, π, may be expressed as 3.14159... and the value for 1/3 as 0.333.... Since many problems are long, with extended calculations, round-off discrepancies will occur and this can give slightly different answers to the same problem. The emphasis has been placed on giving methods and solutions that the students and readers can closely match and be satisfied with their methodology for solving the practice problems.

When giving the solutions to a large number of problems, particularly when there is such a wide variety of problems and a dual system of units (SI and English) to consider, there will be errors and discrepancies. The author and publisher appreciate all of the comments and suggestions made by those readers of the past editions and we solicit your input regarding any corrections or suggested revisions to this edition as well.

Finally, I want to thank all of the users of the earlier editions of this textbook and manual. In many ways you contributed to developing a more accurate and clear publication. I appreciate the work done by Dan Mueller in preparing the programs in a windows format and Hans Jensen for doing some editorial work on those programs. James Wiese and Andrew Cravens helped in facilitating the preparation of the CD as well. I also want to thank Debbie Yarnell and Jon Tenthoff at Prentice-Hall who provided the environment for creating this sixth edition. Again, I hope that you find this manual useful and complimentary to the textbook.

Kurt C. Rolle
Summer, 2004

TABLE OF CONTENTS

Thermodynamics and Heat Power has been written to provide the engineering and engineering technology students with a textbook that attempts to cover the most important aspects of thermodynamics and its technological applications. The text is intended to provide enough depth in the coverage as well as a variety of topics so that it may be used in a number of special emphasis or distinct courses. It can be supplemented with a set of BASIC programs, available from the publisher on a diskette for use with a personal computer, that allows for computer aided instruction of some of the material.

The following lesson plans have been set down as suggested approaches for some specific course work. The lesson plans are written for two or three hour semester courses and include those topics and sections from the text that would be considered. There is usually enough material in the book sections to spend more time than indicated in the lesson plans. Individual experiences will give each instructor added insights into improved variations from these plans.

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LESSON PLAN 1

3 Semester credits of **HEAT POWER**

Week	Topics	Book Sections
1	Introduction, System	Chapters 1 and 2
2	Work, Power, and Heat	Sections 3.1-3.3
3	Energy and Conservation of Mass	Sections 3.4-4.2
4	Steady Flow Energy Equation	Sections 4.3-4.6
5	Conservation of Energy	Sections 4.7-4.9
6	Equations of State	Chapter 5
7	Processes	Sections 6.1-6.4
8	Carnot Cycle and Entropy	Sections 7.1-7.8
9	Otto Cycle	Sections 9.1-9.4
10	Diesel and Dual Cycles	Sections 9.5-9.10
11	Gas Turbines	Sections 10.1-10.5,10.9
12	Steam Turbine Power Cycles	Sections 11.1-11.6
13	Analysis of Rankine Cycles	Sections 11.7-11.11
14	Refrigeration Cycles	Sections 12.1-12.3
15	Mixtures and Psychometrics	Sections 13.1-13.4
16	Combustion Analysis	Sections 14.1-14.5

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LESSON PLAN 2

2 Semester Credits of HEAT POWER

Week	Topics	Book Sections
1	Introduction	Chapter 1
2	System	Chapter 2
3	Work and power	Sections 3.1-3.2
4	Heat, energy, and conservation of mass	Sections 3.3-3.7 and 4.1-4.2
5	Conservation of energy	Sections 4.3-4.5.4.8
6	Equations of state, Perfect gas	Sections 5.1-5.3
7	Properties of pure substance	Sections 5.4-5.6
8	Processes of perfect gases	Sections 6.1-6.2
9	Processes of pure substances	Sections 6.6-6.7
10	Carnot cycle	Sections 7.1-7.5
11	Otto cycle	Sections 9.1-9.3
12	Diesel cycle	Sections 9.5-9.7
13	Rankine cycle	Sections 11.1-11.7
14	Refrigeration	Sections 12.1-12.3
15	Mixtures, combustion	Sections 13.1-13.2 14.1
16	Combustion	Sections 14.2-14.5

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LESSON PLAN 3

2 Semester credits of POWER PLANTS

Week	Topics	Book Sections
1	Introduction, systems	Chapters 1 and 2
2	Work, power, and heat	Chapter 3
3	Conservation and mass and energy	Chapter 4
4	Properties of pure substances	Chapter 5
5	Processes of steam, heat engines	Sections 6.6,7.1, 7.2
6	Thermal efficiency	Sections 7.3-7.6
7	Isentropic processes	Sections 7.7,7.8
8	Rankine cycle components	Sections 11.1-11.5
9	Analysis of rankine cycles	Sections 11.6,11.7
10	Reheat cycle	Section 11.8
11	Regenerative cycle	Section 11.9
12	Reheat-regenerative cycles	Sections 11.10,11.11
13	Gas turbine analysis	Sections 10.1,10.2, 10.5
14	Regenerative gas turbines electric generators	Sections 10.6,10.7, 17.1
15	Combustion processes	Sections 14.1-14.3
16	Combustion analysis	Sections 14.4-14.8

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LESSON PLAN 4

3 Semester credits of **INTRODUCTORY THERMODYNAMICS** followed by a second
3 semester credits of **APPLIED THERMODYNAMICS**.

Week	Topics	Book Sections
1	Introduction	Chapter 1
2	System and properties	Chapter 2
3	Work, power, and heat	Sections 3.1-3.3
4	Energy forms and types	Sections 3.4-3.8
5	Conservation of mass and energy	Sections 4.1-4.6
6	Steady flow energy equation	Sections 4.7-4.9
7	Equations of state	Sections 5.1-5.3
8	Calorimetry	Sections 5.4-5.6
9	Processes of perfect gases	Sections 6.1-6.2
10	Processes of liquids and solids	Sections 6.3-6.5
11	Processes of pure substances	Section 6.6
12	Heat engines and heat pumps	Sections 7.1-7.5
13	Entropy and the third law	Sections 7.6-7.9
14	Carnot cycle analysis	Sections 7.10-7.11
15	Useful work and availability	Sections 8.1-8.3
16	Free energies	Section 8.4

3 Semester credits of **APPLIED THERMODYNAMICS**

Week	Topics	Book Sections
1	Otto cycle analysis	Sections 9.1-9.4
2	Diesel and dual cycles	Sections 9.5-9.8
3	Brayton cycle components	Sections 10.1-10.4
4	Gas turbine, jet propulsion	Sections 10.5-10.7 10.9
5	Rankine cycle components	Sections 11.1-11.6
6	Analysis of rankine cycles	Sections 11.7-11.11
7	Vapor compression cycles	Sections 12.1-12.3
8	Air cycle, cryogenics, heat pumps	Sections 12.4, 12.6, 12.7,12.8
9	Mixture analysis	Sections 13.1-13.3
10	Processes of water-air mixtures	Sections 13.4-13.7
11	Combustion processes	Sections 14.1-14.3
12	Combustion analysis	Sections 14.4-14.8
13	Conduction, convection heat transfer	Sections 15.1-15.3
14	Radiation, heat exchangers	Sections 15.6-15.8
15	Electrical processes	Sections 17.1-17.3
16	MHD, bio-systems, Stirling cycle	Sections 17.4-17.7

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LESSON PLAN 5

2 semester credits of **THERMODYNAMICS** followed by a second 2 semester credits of **APPLIED THERMODYNAMICS**

Week	Topics	Book Sections
1	Introduction	Chapter 1
2	System, pressure, density	Sections 2.1-2.9
3	Temperature, energy	Sections 2.10-2.14
4	Work, power, and heat	Sections 3.1-3.3
5	Reversibility, energy forms	Sections 3.4-3.8
6	Conservation of mass and energy	Sections 4.1,4.2,4.4
7	Steady flow energy equation	Sections 4.5-4.9
8	Equations of state	Sections 5.1-5.3
9	Properties of pure substances	Sections 5.5-5.6
10	Processes of perfect gases	Sections 6.1,6.2
11	Processes of pure substances	Sections 6.3-6.7
12	Heat engines	Sections 7.1,7.2
13	Thermal efficiency	Sections 7.3,7.4
14	Entropy	Sections 7.5,7.6
15	Isentropic processes	Sections 7.7-7.9
16	Carnot cycle analysis	Section 7.10

2 Semester credits of **APPLIED THERMODYNAMICS**

Week	Topics	Book Sections
1	Otto cycles	Sections 9.1-9.3
2	Diesel cycles	Sections 9.4,9.5
3	Diesel and dual cycles	Sections 9.6-9.8
4	Brayton cycle	Sections 10.1-10.4
5	Gas turbine analysis	Section 10.5
6	Rankine cycle	Sections 11.1-11.3
7	Analysis of rankine cycles	Sections 11.4-11.7
8	Reheat and regeneration	Sections 11.8-11.9
9	Reheat-regeneration cycles	Section 11.10
10	Vapor compression refrigeration	Sections 12.1-12.3
11	Heat pumps, mixture analysis	Sections 12.7,13.1
12	Psychometrics	Sections 13.2-13.4
13	Combustion processes	Sections 14.1-14.3
14	Combustion analysis	Sections 14.4,14.5
15	Heat transfer	Sections 15.1-15.3
16	Other applications	Chapter 17

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LESSON PLAN 6

2 Semester credits of **HEAT TRANSFER**

Week	Topics	Book Sections
1	Review of terms	Chapters 1 and 2
2	Work, power, and heat	Sections 3.1-3.3
3	Conduction heat transfer	Section 15.1
4	Conservation of mass	Sections 4.1-4.4
5	First law of thermodynamics	Sections 4.5,4.6
6	Steady flow energy equation	Sections 4.7,4.8
7	Properties of pure substances	Sections 5.3,5.5
8	Processes of fluids and solids	Sections 6.4-6.6
9	Convection heat transfer	Section 15.2
10	Fins	Section 15.3
11	Lumped heat capacity	Section 15.3
12	Forced convection	Section 15.4
13	Natural convection	Section 15.5
14	Radiation heat transfer	Section 15.6
15	Radiation analysis	Section 15.6
16	Heat Exchangers	Section 15.7

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LESSON PLAN 7

3 Semester credits of **HEAT TRANSFER**

Week	Topics	Book Sections
1	Introduction, review of terms	Chapters 1 and 2
2	Work, heat and mass flow	Sections 3.1-3.3, 4.1,4.2
3	Conservation of energy and equations of state	Sections 4.4,4.5 5.1,5.3
4	Processes of fluids and solids	Sections 6.4-6.6
5	Conduction heat transfer	Section 15.1
6	Convection heat transfer	Section 15.2
7	Fins, lumped heat capacity	Section 15.3
8	Flow of fluids, pure substances	Sections 4.7,4.8, 5.5
9	Forced convection	Section 15.4
10	Natural convection	Section 15.5
11	Radiation heat transfer	Section 15.6
12	Radiation analysis	Section 15.6
13	Heat exchangers	Section 15.7
14	Psychometrics	Sections 13.1-13.4
15	Analysis of heating	Sections 16.1,16.2
16	analysis of air conditioning	Section 16.3

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LESSON PLAN 8

2 Semester credits of **INTERNAL COMBUSTION ENGINES**

Week	Topics	Book Sections
1	Introduction, system	Chapters 1 and 2
2	Work, power, and heat	Sections 3.1-3.4
3	Conservation of mass	Sections 4.1-4.4
4	Conservation of energy	Sections 4.5,4.7, 4.8
5	Equations of state	Sections 5.1-5.3
6	Processes of perfect gases	Sections 6.1,6.2
7	Carnot heat engine	Sections 7.1-7.3, 7.5
8	Isentropic processes	Sections 7.6-7.8
9	Carnot cycle analysis	Sections 7.10,9.1
10	Otto cycle analysis	Sections 9.2-9.4
11	Diesel and dual cycles	Sections 9.5-9.7
12	Computer aided analysis	Sections 9.8-9.10
13	Brayton cycle	Sections 10.1-10.4
14	Gas turbine analysis	Section 10.5
15	Regenerative cycles	Sections 10.6,10.7
16	Computer aided analysis of gas turbines	Section 10.9

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LESSON PLAN 9

3 Semester credits of **INTERNAL COMBUSTION ENGINES**

Week	Topics	Book Sections
1	Introduction, system	Chapters 1 and 2
2	Work, power, and heat	Chapter 3
3	Conservation of mass and energy	Sections 4.1,4.2, 4.4,4.5,4.8
4	Equations of state	Sections 5.1-5.3
5	Processes of gases, heat engines	Sections 6.1,6.2,7.1
6	Carnot heat engine	Sections 7.2-7.5
7	Isentropic processes	Sections 7.6-7.8
8	Carnot cycle analysis	Sections 7.9,7.10
9	Otto cycle analysis	Sections 9.1-9.4
10	Diesel engines	Sections 9.5,9.6
11	Dual cycle analysis	Sections 9.7-9.10
12	Brayton cycle	Sections 10.1-10.3
13	Gas turbine analysis	Sections 10.4,10.5
14	Regenerative cycles	Section 10.6
15	Jet propulsion	Sections 10.7,10.9
16	Rockets, Stirling engine	Sections 10.8,17.6

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LESSON PLAN 10

3 Semester credits of **HEATING AND AIR CONDITIONING**

Week	Topics	Book Sections
1	Introduction, system	Chapters 1 and 2
2	Work and heat	Chapter 3
3	Conservation of mass and energy	Sections 4.1,4.2,4.4
4	Steady flow energy equation	Sections 4.5-4.9
5	Property equations	Sections 5.1,5.3,5.5
6	Processes of perfect gases and pure substances	Sections 6.1,6.4,6.6
7	Heat pump analysis	Sections 7.1,7.4,7.10
8	Vapor compression refrigeration	Sections 12.1-12.3
9	Air cycle analysis	Sections 12.4,12.5
10	Cryogenics	Sections 12.6,12.7
11	Mixtures and psychometrics	Sections 13.1-13.4
12	Conduction and convection	Sections 15.1-15.3
13	Heat exchangers	Sections 15.5,15.7
14	Parameters in heating and air conditioning	Section 16.1
15	Analysis of heating	Section 16.2
16	Analysis of air conditioning,	Sections 16.3,17.6

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LESSON PLAN 11

2 Semester credits of HEATING AND AIR CONDITIONING

Week	Topics	Book Sections
1	Introduction	Chapter 1
2	System and properties	Chapter 2
3	Work, power, and heat	Chapter 3
4	Conservation of mass	Sections 4.1,4.2
5	Conservation of energy	Sections 4.4,4.5,4.8
6	Equations of state	Sections 5.1-5.3
7	Pure substances	Sections 5.5,6.1
8	Perfect gases and incompressible substances	Sections 6.2,6.4
9	Processes of pure substances	Sections 6.6,7.1
10	Carnot heat pump	Sections 7.2-7.4
11	Vapor compression refrigeration	Sections 12.1-12.3
12	Conduction and convection	Sections 15.1,15.2
13	Applications of heat transfer	Section 15.3
14	Parameters in heating and a/c	Section 16.1
15	Analysis of space heating	Section 16.2
16	Analysis of air conditioning	Section 16.3

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Basic Thermodynamics for Engineers

Course Information

Description:

Thermodynamic systems, Properties, zeroth law of thermodynamics, conservation of mass and energy, first and second laws of thermodynamics, Ideal gases, steam, Refrigerants, Power and refrigeration cycles, Heat Transfer.

Text:

Thermodynamics and Heat Power, Fifth Edition, K.C.Rolle

Prerequisites:

Physics Mechanics, Heat light and Sound
Differential and Integral Calculus

Requirements:

The student is expected to attend class, be prepared by reading the assignments for the day, and do the practice problems.

Grading:

The students semester grades will be based on examinations, homework, and bonus quizzes. There will be 4 examinations, each examination pertaining to the material covered since the last examination and each based on 100 points. The homework is due on the days indicated on the semester schedule. Each homework problem is worth 5 points maximum; that is,

5 points - done correctly
4 points - done with calculation error
3 points - done with conceptual error
2 points - done with more than one error
1 point - attempted

There will be 16 homework problems due. There will also be 5 quizzes, unannounced and closed-book each worth 5 points. These are Bonus Points and if you miss the quiz by being late or absent from class it cannot be made up. The semester grade will be determined by the semester percentage score (SPS).

$$SPS = \frac{\text{Students test scores, homework, and quizzes}}{480}$$

Letter grades will be assigned by the scientific scale:

A 90 to 100%
B 80 to 89%
C 70 to 79%
D 60 to 69%
F Below 60%

Thermodynamics for Engineers

Semester Schedule

Class	Topics	Readings	Practice Problems	Home Work
1	Introduction, Units	1.1 thru 1.8	1.5, 1.6	
2	System and properties	2.1 thru 2.7	1.14,1.22,	
3	Pressure, Temperature,	2.8 through 2.13	1.26,1.28 1.30, 2.16	
4	Work and Power	3.1,3.2	2.18,2.25 2.24, 2.35 2.40, 2.43	
5	Heat and Energy Forms	3.3-3.7	3.10. 3.14 3.24, 3.25	**2.27**
6	Conservation of Mass and Steady Flow	4.1,4.2	4.2,4.8 4.10,4.18	**3.9**
7	Uniform Flow and Unsteady Flow	4.3,4.4	4.20,4.22	**4.25**
8	First Law of Thermo	4.5-4.8	4.38,4.40	**4.57**
9	Problem Session		4.44,4.48 4.41	
10	Review			
11	**Examination One**			
12	Equations of state	5.1,5.2	5.2,5.4 5.10	
13	Calorimetry	5.3,5.4	5.16,5.20 5.28,5.30, 5.38	**5.23**
14	Properties of Pure Substances	5.5	5.54,5.58 5.66, 5.45	**5.43**

Class	Topics	Readings	Practice Problems	Home Work
15	Processes	6.1	6.2,6.8	
16	Adiabatic Processes of Perfect Gas	6.2	6.12, 6.20	
17	Processes of Comp.Gases	6.3	6.26, 6.30	**6.35**
18	Processes of Liquids and Solids	6.4-6.5	6.43, 6.44 6.50, 6.52	
19	Processes of Pure Substances		6.58, 6.62 6.68, 6.77 6.85	
20	Review			
21	**Examination Two**			
22	Heat Engines	7.1-7.4	7.2,7.4	
23	Carnot Cycle Heat Pumps		7.6, 7.8 7.12	
24	Second Law of Thermo	7.5-7.6	7.16, 7.18	**7.13**
25	Entropy Isentropic Processes	7.7-7.9	7.20, 7.24 7.26	
26	Mixtures	13.1-13.2	13.2, 13.3	**7.29**
27	Psychrometrics	13.3	13.4, 13.6	
28	Psychrometric Processes	13.4	13.12,13.14	
29	Rankine Cycle	11.1-11.7	13.16, 13.18 13.26	
30	Rankine Cycle Analysis	11.8-11.9	11.5,11.12 11.20, 11.28	
31	Refrigeration Cycles	12.1-12.4	12.2, 12.6, 12.10, 12. 11,	**13.25**

Class	Topics	Readings	Practice Problems	Home Work
32	Problem Session		12.17, 12.18	
33	Review			
34	**Examination Three**			
35	Conduction Heat Transfer	15.1	15.2, 15.6, 15.10	**15.2**
36	Convection Heat Transfer	15.2	15.12,15.14	
37	Conduction/Convection	15.3	15.20,15.24 15.28	
38	Forced and Free Convection	15.4 15.5	15.30, 15.36 15.40, 15.39	**15.21**
39	Radiation Heat Transfer	15.6	15.44, 15.50	
40	Heat Exchangers	15.7	15.54, 15.55	
41	Useful Work	8.1, 8.2	8.2, 8.8	**15.31**
42	Availability and Free Energy	8.3, 8.4	8.10, 8.12	**15.49**
43	Review		8.13, 8.16	**8.9**
44	**Examination Four**			

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CHAPTER 1

THE PROBLEMS IN SECTION 1.4 ARE INTENDED TO PROVIDE A REVIEW OF ARITHMETIC, ALGEBRAIC, AND TRIGONOMETRIC OPERATIONS.

1.1. $\dfrac{(3.70)(40.1)}{(136)(270)(3)} = \underline{0.0013468....}$

1.2. $(1870)(26.0)(9.80) = \underline{476,476}$

1.3. $260^2 = \underline{67,600}$

1.4. $260^{1/4} = \underline{4.0155....}$

1.5. $(62.1)\left(\dfrac{35.1}{26.1}\right)^{1.6} = \underline{99.76....}$

1.6. $(333)\left(\dfrac{1}{1-1.2}\right) = \underline{-1665}$

1.7 a.) $1.3 \sin 25° = \underline{0.5494...}$

b.) $3.7 \sin\left(\frac{2\pi}{9}\right) = 3.7 \sin(40°) = \underline{2.378....}$

1.8 a.) $(5.6\ kJ)\cos 160° = \underline{-5.262..\ kJ}$

b.) $\left(9.1\ \frac{BTU}{lbm}\right)\cos\frac{\pi}{16} = 9.1\cos 11.25° = \underline{8.925..\ \frac{BTU}{lbm}}$

CHAPTER 1

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Class	Topics	Readings	Practice Problems	Home Work
32	Problem Session		12.17, 12.18	
33	Review			
34	**Examination Three**			
35	Conduction Heat Transfer	15.1	15.2, 15.6, 15.10	**15.2**
36	Convection Heat Transfer	15.2	15.12,15.14	
37	Conduction/Convection	15.3	15.20,15.24 15.28	
38	Forced and Free Convection	15.4 15.5	15.30, 15.36 15.40, 15.39	**15.21**
39	Radiation Heat Transfer	15.6	15.44, 15.50	
40	Heat Exchangers	15.7	15.54, 15.55	
41	Useful Work	8.1, 8.2	8.2, 8.8	**15.31**
42	Availability and Free Energy	8.3, 8.4	8.10, 8.12	**15.49**
43	Review		8.13, 8.16	**8.9**
44	**Examination Four**			

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1.9. a.) $6.48 \log(37.6) = \underline{10.2072\ldots}$

b.) $(0.2\ kN\text{-}m)\ln(37000) = \underline{2.1037\ldots\ kN\text{-}m}$

1.10 $e^{1.7} = \underline{5.4739\ldots}$

$e^{-20.0} = \underline{(2.061\ldots)\times 10^{-9}}$

$e^{\pi/2} = \underline{4.810\ldots}$

1.11 SOLVE FOR P:

$$3P + 17 = 22\cos 28^\circ$$

$$3P = 22\cos 28^\circ - 17$$

$$P = (22\cos 28^\circ - 17)/3$$

$$\underline{P = 0.808\ldots\ psi}$$

1.12 SOLVE FOR x; $x^3 = 324$

$$x = 324^{1/3} = \underline{6.868\ldots\ ft}$$

1.13 SOLVE FOR V:

$$V^2 + 2V = 265\ m^6$$

THIS IS A QUADRATIC EQUATION AND

$$V = \frac{-2 \pm \sqrt{(2)^2 - 4(1)(-265)}}{2(1)} = \underline{15.3\ m^3}$$

THE SOLUTION $V = -17.3\ldots$ IS NOT A REAL SOLUTION.

1.14. SOLVE FOR T:

$$27.315\ ^\circ C = 27.600^\circ C - 0.003T$$

$$0.003T = 27.600 - 27.315 = 0.285$$

$$T = 0.285 / 0.003$$

$$\underline{T = 95^\circ C}$$

1.15 SOLVE $pV = mRT$ FOR T. WE HAVE

$$\underline{T = \frac{pV}{mR}}$$

1.16 FOR $xy^{1.6} = 2.3$

$$\underline{x = \frac{2.3}{y^{1.6}}} \qquad \underline{y = \left(\frac{2.3}{x}\right)^{1/1.6}}$$

PROBLEMS IN SECTION 1.5 PROVIDE SOME PRACTICE IN APPROXIMATING AREAS UNDER CURVES AND USING TRAPEZOID RULE.

1.17. AREA UNDER CURVE = AREA OF RECTANGLE

$$= \text{BASE} \times \text{HEIGHT}$$

$$= (1.5\,m^3 - .06\,m^3)\left(500\ \frac{kN}{m^2}\right)$$

$$= 720\ \frac{kN\text{-}m^3}{m^2}$$

$$\underline{= 720\ kN\text{-}m}$$

1.18. AREA UNDER CURVE = AREA OF TRAPEZOID

$$A = \frac{1}{2}(\text{BASE})(\text{SUM OF TWO SIDES})$$

$$A = \frac{1}{2}(100°C - 10°C)(C_v @ 100°C + C_v @ 10°C)$$

$$C_v @ 100°C = 3.5 + .01 \times 100 = 4.5 \; kJ/kg\,C$$

$$C_v @ 10°C = 3.5 + .01 \times 10 = 3.6 \; kJ/kg\,C$$

SO $A = \frac{1}{2}(90°C)\left(4.5 + 3.6 \frac{kJ}{kg\,C}\right)$

$$= 364.5 \; kJ/kg$$

1.19. AREA UNDER CURVE = A = AREA UNDER CURVE WHERE y VARIES INVERSELY WITH x AS IN APPENDIX A.4d.

$$A = C \ln V_2/V_1$$

WHERE $C = 50{,}000 \frac{lbf}{ft^2} \times 1.0 ft^3 = 50{,}000 \; ft\text{-}lbf$

SO

$$A = (50{,}000 \; ft\text{-}lbf) \ln 4.0/1.0$$

$$= 69{,}314.7 \; ft\text{-}lbf.$$

AN ALTERNATE APPROXIMATE SOLUTION CAN BE OBTAINED BY USING SMALL TRAPEZOID AREAS SUMMED AS IN APPENDIX FIG Ax.1

AS ONE EXAMPLE OF THIS, USING 3 TRAPEZOIDAL AREAS :

$V_1 = 1.0\ ft^3$ $\quad P_1 = 50{,}000\ lbf/ft^2$

$V_2 = 2.0\ ft^3$ $\quad P_2 = 25{,}000$

$V_3 = 3.0\ ft^3$ $\quad P_3 = 16{,}667$

$V_4 = 4.0\ ft^3$ $\quad P_4 = 12{,}500$

THEN THE AREA CAN BE APPROXIMATED

$$A \approx \frac{1}{2}(V_2 - V_1)(P_2 + P_1) + \frac{1}{2}(V_3 - V_2)(P_3 + P_2) + \frac{1}{2}(V_4 - V_3)(P_4 + P_3)$$

$$\approx \frac{1}{2}(1\ ft^3)\left(75{,}000\ \frac{lbf}{ft^2}\right) + \frac{1}{2}(1)(41{,}667) + \frac{1}{2}(1)(29{,}167) = \underline{72{,}917\ ft\text{-}lbf}$$

THIS PROBLEM CAN ALSO BE SOLVED BY USING COMPUTER PROGRAM <u>AREA</u> AND MICRO COMPUTER.

1.20 AREA UNDER CURVE = A = AREA UNDER A CURVE $y = B/x^n$ WHERE $y = P$, $x = V$ $n = 1.5$ $B = C$ IN APPENDIX A4.e.

THEN

$$A = \frac{1}{1-n}\left(p_2 V_2 - p_1 V_1\right)$$

WHERE $V_1 = 15.0 \text{ in}^3$

$P_2 = 20.0 \text{ lbf/in}^3$

$V_2 = 100.0 \text{ in}^3$

$$P_1 = P_2\left(\frac{V_2}{V_1}\right)^{1.5} = 20.0\left(\frac{100}{15.0}\right)^{1.5} = 344.265$$

AND

$$A = \frac{1}{1-1.5}\left(20.0 \times 100.0 - 344.265 \times 15.0\right)$$

$$= 6327.95 \ \frac{\text{lbf-in}^3}{\text{in}^2} = \underline{6327.95 \text{ in-lbf}}$$

1.21 APPROXIMATE AREA UNDER CURVE = A

AND

A = SUM OF SMALL TRAPEZOIDAL AREAS.

$$= \frac{1}{2}(.0108 - .01 \text{ ft}^3)(1000 + 900 \text{ lbf/in}^2)$$

$$+ \frac{1}{2}(.0117 - .0108)(900 + 800) + \frac{1}{2}(.0130 - .0117)$$

$$(800 + 700) + \frac{1}{2}(.0145 - .0130)(700 + 600)$$

$$+ \frac{1}{2}(.0160 - .0145)(600 + 500) + \frac{1}{2}(.020 -$$

$$.0160)(500 + 400) = 6.1 \ \frac{\text{lbf-ft}^3}{\text{in}^2}$$

$$= \underline{878.4 \text{ ft-lbf}}$$

1.22. AREA UNDER CURVE ON T-S DIAGRAM = A
$A \cong$ SUM OF TRAPEZOIDAL AREAS.

THIS CAN BE DONE USING SAME SORT OF CALCULATION AS IN PROBLEM 1.21 OR BY USING PROGRAM AREA AND A MICRO COMPUTER. INPUT TO THE PROGRAM AREA WILL BE N=7, AND

Y(1) = 3400 , X(1) = 6.78
Y(2) = 3500 , X(2) = 6.81
Y(3) = 3600 , X(3) = 6.831
Y(4) = 3700 , X(4) = 6.873
Y(5) = 3800 , X(5) = 6.904
Y(6) = 3900 , X(6) = 6.942
Y(7) = 4000 , X(7) = 6.960

THE RESULT IS $A = 665 \text{ kJ/kg}$

1-23 AREA UNDER CURVE ON T-S DIAGRAM = A
$A \approx$ SUM OF TRAPEZOIDAL AREAS.

THIS CAN BE DONE USING SAME SORT OF CALCULATIONS AS IN PROBLEM 1-21 OR BY USING PROGRAM AREA AND

A MICRO COMPUTER. INPUT TO THE PROGRAM AREA WILL BE ; N = 5 AND

Y(1) = 500 , X(1) = 3.456
Y(2) = 600 , X(2) = 3.789
Y(3) = 700 , X(3) = 3.954
Y(4) = 800 , X(4) = 4.002
Y(5) = 900 , X(5) = 4.011

THE RESULT IS A = 334.05 BTU

1.24 FOR p = 20.5 V WE FIND p AT V OF FROM 1 TO 10 :

P	V
20.5	1
41.0	2
61.5	3
82.0	4
102.5	5
123.0	6
143.5	7
164.0	8
184.5	9
205.0	10

THE AREA UNDER THE CURVE $p = 20.5V$ IS APPROXIMATED BY THE SUM OF TRAPEZOID AREAS, USING THE METHOD OF PROBLEM 1.21 OR USING PROGRAM <u>AREA</u> AND A PERSONAL COMPUTER. INPUT TO THE PROGAM COULD BE N= 10 AND VALUES OF P FOR THE Y-VALUES AND V FOR THE X-VALUES. THE RESULT IS

$$\underline{A = 1014.75}$$

USING CALCULUS:

$$A = \int_1^{10} p\,dv = \int_1^{10} f(v)\,dv = \int_1^{10} 20.5\,v\,dv$$

$$= \frac{1}{2}(20.5)v^2\Big|_1^{10} = \frac{1}{2}(20.5)(100-1)$$

$$\underline{A = 1014.75}$$

1.25 FOR THE CHANGE IN INTERNAL ENERGY OF A PERFECT GAS, Δu, WE HAVE

$$\Delta u \approx \sum_{n=1}^{N} c_v \delta T = \text{AREA UNDER A CURVE IN } c_v - T \text{ DIAGRAM.}$$

1.25 (CONT.) USING δT OF 50 DEGREES, WE CALCULATE C_V AT T = 100 TO T = 500: $C_V = 3.56 + .0346T$

$C_V = 7.02$, T = 100

$C_V = 8.75$, T = 150

$C_V = 10.48$, T = 200

$C_V = 12.21$, T = 250

$C_V = 13.94$, T = 300

$C_V = 15.67$, T = 350

$C_V = 17.40$, T = 400

$C_V = 19.13$, T = 450

$C_V = 20.86$, T = 500

USING AREA AND A PERSONAL COMPUTER WITH INPUTS OF N = 10, C_V-VALUES FOR Y-VALUES, AND T FOR X-VALUES, THE RESULT IS

$$\Delta u = 5576 \text{ kJ/kg}$$

USING CALCULUS:

$$\Delta u = \int_{100}^{500} C_V \, dT = \int_{100}^{500} (3.56 + .0346T) \, dT$$

$$= 3.56T + \frac{1}{2}(.0346T^2) \Big|_{100}^{500}$$

$$\Delta u = 5576 \text{ kJ/kg}$$

1.26 AREA UNDER CURVE OF $pv^{1/2} = 2700$ IS GIVEN IN APPENDIX A.4e:

$$A = \frac{2700}{1-1/2}\left(300^{1/2} - 10^{1/2}\right) = 76454.44$$

THE SAME AREA CAN BE APPROXIMATED BY THE SUM OF TRAPEZOIDAL AREAS. USING AREA AND A PERSONAL COMPUTER WITH N = 30 AND VALUES OF P FOR Y-VALUES AND V (FROM 10 TO 300 IN INCREMENTS OF 10) FOR X. VALUES OF P ARE DETERMINED FROM $p = 2700/\sqrt{v}$ SO THAT, AT V = 10, p = 853.8; AT V = 20, p = 603.7 AND SO ON. PROGRAM AREA NEEDS TO BE REVISED TO RUN THIS PROBLEM WITH 30 POINTS. CHANGE LINE 100 TO READ:

```
100   DIM X(31)
```

AND LINE 110 TO READ:

```
110   DIM Y(31)
```

1.26 (CONT.) THEN THE COMPUTER RUN WILL GIVE

$\underline{A = 76788.2}$ (DEPENDING ON ROUND-OFF OF p-VALUES)

THE PROBLEMS IN SECTION 1.7 ARE INTENDED TO PROVIDE PRACTICE IN USING ENGINEERING EQUATION SOLVER (EES)

1.27 OPENING EES EQUATION WINDOW AND ENTERING:

```
{Problem 1-27}

x+2*y=3.4
x**2+y**2=4.5
```

THEN CLICKING CALCULATE AND THEN SOLVE GIVES:

Unit Settings: [kJ]/[C]/[kPa]/[kg]/[degrees]
x = 2.003 y = 0.6985

No unit consistency or conversion problems were detected.

1.28 OPENING EES EQUATION WINDOW AND ENTERING:

```
{Problem 1-28}

s=3.458
T*s**1.4=4456
```

THEN CLICK CALCULATE ON THE TOOLBAR AND SOLVE GIVES:

```
Unit Settings: [kJ]/[C]/[kPa]/[kg]/[degrees]
s = 3.458                                        T = 784.5

No unit consistency or conversion problems were detected.
```

1.29 OPEN EES EQUATION WINDOW AND ENTER:

```
{Problem 1-29}

p*V**1.4=280
```

THEN CLICK TABLES ON TOOLBAR AND NEW PARAMETRIC TABLE SET NO. OF RUNS TO 20, PUT P AND V IN VARIABLES IN TABLE BY CLICKING ON P, THEN ADD, THEN ON V, AND ADD. CLICK

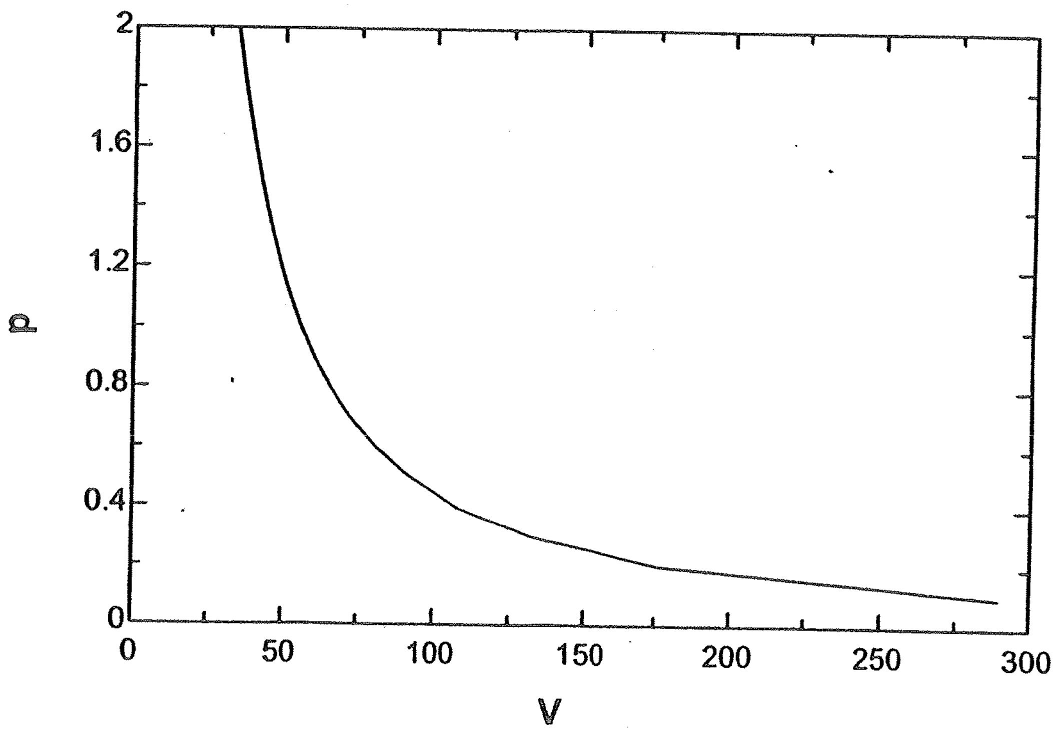
1.29 (CONT.)

OK AND ENTER ALL VALUES FOR ρ FROM 0.1 TO 2. THEN CLICK CALCULATE AND SOLVE TABLE. CLICK OK AND RESULT IS:

Parametric Table: Table 1

	p	V
Run 1	0.1	289.9
Run 2	0.2	176.7
Run 3	0.3	132.3
Run 4	0.4	107.7
Run 5	0.5	91.83
Run 6	0.6	80.62
Run 7	0.7	72.21
Run 8	0.8	65.64
Run 9	0.9	60.35
Run 10	1	55.97
Run 11	1.1	52.29
Run 12	1.2	49.14
Run 13	1.3	46.41
Run 14	1.4	44.01
Run 15	1.5	41.9
Run 16	1.6	40.01
Run 17	1.7	38.31
Run 18	1.8	36.78
Run 19	1.9	35.39
Run 20	2	34.12

1.30 TO PLOT RESULTS OF PROBLEM 1.29, CLICK PLOTS ON TOOLBAR, THEN NEW PLOTS WINDOW. CLICK V FOR X-AXIS AND P FOR Y-AXIS. THEN CLICK OK AND PLOT RESULTS:



1.31 OPEN EES EQUATION WINDOW AND ENTER:

```
{Problem 1-31}

Wk=p*v**1.4
p*v=4.56*T
Wk=Q-0.234*T
Q=456/T
T=23*p
```

THEN CLICK CALCULATE AND SOLVE TO OBTAIN:

Unit Settings: [kJ]/[C]/[kPa]/[kg]/[degrees]

p = 0.1708 Q = 116.1 T = 3.928 v = 104.9

Wk = 115.2

No unit consistency or conversion problems were detected.

Chapter 2 Discussion Questions

Section 2.1

2.1 A *system* is a region in space having at least a volume.

2.2 A system needs a boundary to define the volume of that system.

Section 2.2

2.3 A *mole* or *mol* is a given number of molecules or atoms. Avogadro's Number is the number of molecules or atoms in one mole based on a gram. That is, one gram-mole of a substance has 6.022×10^{23} atoms or molecules, which is Avogadro's number.

2.4 Yes, a gram-mole is only 1/454 of a lbm-mol.

Section 2.3

2.5 A property helps describe a system.

2.6 Intensive properties of a system are properties based on one unit of mass of the system. Extensive properties describe the total system.

2.7 Specific energy is the energy per unit mass of a system.

Section 2.4

2.8 A state of a system is the complete description of a system, or the list of properties describing the system.

Section 2.5

2.9 A process is a change in a system's state.

Section 2.6

2.10 A cycle is a set of processes of a system which returns the system to its

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1.31 OPEN EES EQUATION WINDOW AND ENTER:

{Problem 1-31}

```
Wk=p*v**1.4
p*v=4.56*T
Wk=Q-0.234*T
Q=456/T
T=23*p
```

THEN CLICK CALCULATE AND SOLVE TO OBTAIN:

Unit Settings: [kJ]/[C]/[kPa]/[kg]/[degrees]

p = 0.1708 Q = 116.1 T = 3.928 v = 104.9

Wk = 115.2

No unit consistency or conversion problems were detected.

original state.

Section 2.7

2.11 Weight is the gravitational attraction between two bodies. The mass is a quantity of matter and weight is mass multiplied by the gravitational acceleration.

2.12 The term g_c is a constant of proportionality between momentum change (or mass times acceleration) and force (or weight)

Section 2.8

2.13 Specific volume is the volume per unit mass of a system.

2.14 Specific weight is the weight per unit volume of a system.

2.15 Specific Gravity is the ratio of the density of a substance to that of water at 4^0 C, standard atmospheric pressure of 1 bar.

2.16 Density is the mass per unit volume, or inverse specific volume.

2.17 Gage pressure is the pressure measured by a gage, usually when the gage is placed in a standard atmosphere of 1 bar pressure. It is a difference in pressure between absolute pressure of a system and the atmospheric pressure. Gage pressure is the pressure "felt" by a system at its boundary.

Section 2.9

2.18 The zeroth law of thermodynamics makes a temperature measurement independent of a system. Thus, a temperature of, say 30 degrees, is the same anywhere and anytime.

Section 2.10

2.19 Temperature is a measure of the "hotness" of a system.

2.20 A thermopile a group of thermocouples, all connected in series to each other.

Section 2.11

2.21 Energy is the capacity of a system to affect changes to its surroundings.

2.22 Internal energy is the form of energy manifested by the hotness or temperature, or the thermal energy. It is the kinetic energy of the individual atmos or molecules making up the system.

Section 2.12

2.23 Some outputs from a system would be, for instance, power produced by an engine, amount of water boiled in a boiler, or an amount of air pressurized in an air compressor.

2.24 Some inputs to a system would be, for instance, rate of fuel used by an engine, amount of energy used by a boiler, or power to drive a compressor.

Section 2.13

2.25 A derived unit is a unit or combination of fundamental units for describing a particular property or quantity.

CHAPTER 2

THE PROBLEMS IN SECTIONS 2.7 AND 2.8 ARE INTENDED TO HELP UNDERSTAND THE CONCEPTS OF WEIGHT, MASS, VOLUME, DENSITY, SPECIFIC VOLUME, AND PRESSURE.

2.1 WEIGHT $W = mg$. THUS, AT $g = 9.8\,m/s^2$

$$W = (2\ kg)(9.8\ m/s^2) = 19.6\ \text{NEWTONS}\ (N)$$

AT $g = 9.78\,m/s^2$

$$W = (2\ kg)(9.78\ m/s^2) = 19.56\ N$$

SO THAT <u>THE GOLD CUBE HAS GREATER WEIGHT AT LOCATION WHERE $g = 9.8\,m/s^2$.</u> THE MASS IS THE SAME AT BOTH LOCATIONS.

2.2 $W = mg = (3\ kg)(9.79\ m/s^2) = \underline{29.37\ N}$

2.3 $W = mg/g_c$ FOR ENGLISH ENGR. UNITS.

SO THAT $m = Wg_c/g$.

AT SEA LEVEL $g = 32.174\ ft/s^2$ SO THAT

$$m = (8.333\ lb_f)\left(32.174\ \frac{ft \cdot lb_m}{lb_f \cdot s^2}\right) \Big/ \left(32.174\ ft/s^2\right)$$

$m = 8.333$ lbm

ALSO, 32.174 lbm = 1 slug SO THAT

$m = 8.333/32.174 = 0.2589\ldots$ SLUGS

2.4 THE MASS OF THE BATTERY IS THE SAME ON THE EARTH AND ON THE MOON.

$$m = W g_c / g = \frac{(32\ \text{lbf})(32.174\ \text{ft}\cdot\text{lbm}/\text{lbf}\cdot\text{s}^2)}{(32.174\ \text{ft}/\text{s}^2)}$$

$= 32$ lbm.

ON THE MOON, WHERE $g = 5.47\ \text{ft}/\text{s}^2$

$$W = mg/g_c = (32\ \text{lbm})(5.47)/(32.174)$$

$W = 5.44..$ lbf

2.5 (a.) 1 lbm = 453.59 grams ≈ 454 grams

(b.) 2 lbm = 2 × 0.45359 kg = 0.90718 kg

(c.) POUNDS-FORCE IS A FORCE OR WEIGHT UNIT. IF $g = 32.174\ \text{ft}/\text{s}^2$ AND SINCE 20 SLUGS IS A MASS, WE HAVE

$$W = mg = (20\ \text{SLUGS})(32.174\ \text{ft}/\text{s}^2)$$

$= 643.48$ lbf

(d.) DYNE IS A FORCE OR WEIGHT UNIT.