

Mahmoud Massoud

Engineering Thermofluids

Thermodynamics, Fluid Mechanics, and Heat Transfer

With 345 Figures and 13 Tables



Table of Contents*

I.	Introduction.....	1
1.	Definition of Thermofluids	1
2.	Energy Sources and Conversion	2
3.	Energy in Perspective.....	4
4.	Power Producing Systems.....	5
5.	Power Producing Systems, Fossil Power Plants	6
6.	Power Producing Systems, Nuclear Power Plants	11
7.	Power Producing Systems, Greenpower Plants	17
8.	Comparison of Various Energy Sources	23
9.	Thermofluid Analysis of Systems	25
	Questions	27
	Problems	28
II.	Thermodynamics	31
IIa.	Fundamentals.....	32
1.	Definition of Terms.....	33
2.	Equation of State for Ideal Gases.....	41
3.	Equation of State for Water	46
4.	Heat, Work, and Thermodynamic Processes	55
5.	Conservation Equation of Mass for a Control Volume.....	64
6.	The First Law of Thermodynamics.....	66
7.	Applications of the First Law, Steady State.....	70
8.	Applications of the First Law, Transient.....	81
9.	The Second Law of Thermodynamics	96
10.	Entropy and the Second Law of Thermodynamics	105
11.	Exergy or Availability.....	116
	Questions	123
	Problems	125
IIb.	Power Cycles	144
1.	Gas Power Systems	144
2.	Vapor Power Systems	161
3.	Actual Versus Ideal Cycles	174

* The related flow chart follows this section

Questions	177
Problems	178
IIc. Mixtures.....	187
1. Mixture of Non-reactive Ideal Gases	187
2. Gases in Contact with Ice, Water, and Steam	193
3. Processes Involving Moist Air.....	196
4. Charging and Discharging Rigid Volumes	203
Questions	217
Problems	218
III. Fluid Mechanics.....	223
IIIa. Single-Phase Flow Fundamentals	224
1. Definition of Fluid Mechanic Terms	224
2. Fluid Kinematics.....	233
3. Conservation Equations	239
Questions	274
Problems	275
IIIb. Incompressible Viscous Flow	286
1. Steady Incompressible Viscous Flow	286
2. Steady Internal Incompressible Viscous Flow	289
3. Pressure Drop in Steady Internal Incompressible Viscous Flow	295
4. Steady Incompressible Viscous Flow in Piping Systems.....	310
5. Steady Incompressible Viscous Flow Distribution in Piping Networks	337
6. Unsteady Internal Incompressible Flow.....	343
7. Fundamentals of Waterhammer Transients	371
Questions	383
Problems	383
IIIc. Compressible Flow	399
1. Steady Internal Compressible Viscous Flow	399
2. The Phenomenon of Choked or Critical Flow	414
Questions	426
Problems	427
IV. Heat Transfer	431
IVa. Conduction.....	431
1. Definition of Heat Conduction Terms	432
2. The Heat Conduction Equation.....	437
3. Analytical Solution of Heat Conduction Equation.....	444

4.	Lumped-Thermal Capacity Method for Transient Heat Conduction.....	445
5.	Analytical Solution of 1-D S-S Heat Conduction Equation, Slab	448
6.	Analytical Solution of 1-D S-S Heat Conduction Equation, Cylinder	461
7.	Analytical Solution of 1-D S-S Heat Conduction Equation, Sphere	474
8.	Analytical Solution of Heat Conduction Equation, Extended Surfaces.....	477
9.	Analytical Solution of Transient Heat Conduction	485
10.	Numerical Solution of Heat Conduction Equation.....	499
	Questions	501
	Problems	502
IVb.	Forced Convection.....	518
1.	Definition of Forced Convection Terms	518
2.	Analytical Solution	521
3.	Empirical Relations.....	534
	Questions	541
	Problems	541
IVc.	Free Convection.....	549
1.	Definition of Free Convection Terms	549
2.	Analytical Solution	550
3.	Empirical Relations.....	553
	Questions	557
	Problems	558
IVd.	Thermal Radiation	561
1.	Definition of Thermal Radiation Terms.....	561
2.	Ideal Surfaces.....	568
3.	Real Surfaces	573
4.	Gray Surfaces.....	578
5.	Radiation Exchange Between Surfaces.....	579
	Questions	592
	Problems	592
V.	Two-Phase Flow and Heat Transfer.....	601
Va.	Two-Phase Flow Fundamentals.....	601
1.	Definition of Two-Phase Flow Terms.....	601
2.	Two-Phase Flow Relation	606
3.	Two-Phase Critical Flow	622
	Questions	632
	Problems	632

Vb.	Boiling	637
1.	Definition of Boiling Heat Transfer Terms.....	637
2.	Convective Boiling, Analytical Solutions.....	641
3.	Convective Boiling, Experimental Observation.....	648
4.	Pool Boiling Modes	650
5.	Flow Boiling Modes	658
	Questions	672
	Problems	673
Vc.	Condensation	677
1.	Definition of Condensation Heat Transfer Terms.....	677
2.	Analytical Solution	678
3.	Empirical Solution	682
4.	Condensation Degradation.....	684
	Questions	685
	Problems	686
VI.	Applications.....	687
Via.	Heat Exchangers.....	687
1.	Definition of Heat Exchanger Terms	687
2.	Analytical Solution	690
3.	Analysis of Shell and Tube Heat Exchanger.....	702
4.	Analysis of Condensers.....	710
5.	Analysis of Steam Generators.....	716
6.	Transient Analysis of Concentric Heat Exchangers.....	719
	Questions	723
	Problems	723
Vib.	Fundamentals of Flow Measurement.....	728
1.	Definition of Flow Measurement Terms.....	728
2.	Repeatability, Accuracy, and Uncertainty	729
3.	Flowmeter Types	732
4.	Flowmeter Installation	744
	Questions	745
	Problems	745
Vic.	Fundamentals of Turbomachines.....	747
1.	Definition of Turbomachine Terms	747
2.	Centrifugal Pumps	749
3.	Dimensionless Centrifugal Pumps Performance.....	755
4.	System and Pump Characteristic Curves	762
5.	Analysis of Hydraulic Turbines.....	769
6.	Analysis of Turbojet for Propulsion.....	777
	Questions	779
	Problems	780

VId. Simulation of Thermofluid Systems	784
1. Definition of Terms.....	784
2. Mathematical Model for a PWR Loop.....	786
3. Simplified PWR Model.....	791
4. Mathematical Model for PWR Components, Pump.....	802
5. Mathematical Model for PWR Components, Pressurizer	811
6. Mathematical Model for PWR Components, Containment	819
7. Mathematical Model for PWR Components, Steam Generator	827
Questions	829
Problems	829
 VIe. Nuclear Heat Generation.....	841
1. Definition of Some Nuclear Engineering Terms.....	841
2. Neutron Transport Equation.....	853
3. Determination of Neutron Flux in an Infinite Cylindrical Core.....	859
4. Reactor Thermal Design	877
5. Shutdown Power Production.....	882
Questions	884
Problems	884
 VII. Engineering Mathematics	901
 VIIa. Fundamentals.....	901
1. Definition of Terms.....	901
 VIIb. Differential Equations	911
1. Famous Differential Equations	911
2. Analytical Solutions to Differential Equations	919
3. Pertinent Functions and Polynomials.....	936
 VIIc. Vector Algebra.....	943
1. Definition of Terms.....	943
 VIId. Linear Algebra.....	963
1. Definition of Terms.....	963
2. The Inverse of a Matrix.....	968
3. Set of Linear Equations.....	971
 VIIe. Numerical Analysis	976
1. Definition of Terms	976
2. Numerical Solution of Ordinary Differential Equations	979
3. Numerical Solutions of Partial Differential Equations.....	985
4. The Newton–Raphson Method	1004
5. Curve Fitting to Experimental Data	1006

VIII. Appendices 1011

 I. Unit Systems, Constants and Numbers 1013

 II. Thermodynamic Data 1023

 III. Pipe and Tube Data 1049

 IV. Thermophysical Data 1059

 V. Nuclear Properties of Elements 1091

References 1097

Index 1111