

# Contents

<b>List of Symbols.....</b>	<b>XV</b>
<b>List of Copyrighted Figures .....</b>	<b>XIX</b>
<b>1 Introduction.....</b>	<b>1</b>
Problems.....	9
<b>2 Linear Partial Differential Equations .....</b>	<b>11</b>
2.1 Classification of Second-Order Partial Differential Equations .....	11
2.2 Character of the Solutions for the Partial Differential Equations .....	19
2.2.1 Parabolic Second-Order Equations .....	19
2.2.2 Elliptic Second-Order Equations .....	21
2.2.3 Hyperbolic Second-Order Equations .....	23
2.3 Separation of Variables .....	24
2.3.1 One-Dimensional Transient Heat Conduction in a Flat Plate.....	24
2.3.2 Steady-State Heat Conduction in a Rectangular Plate.....	31
2.3.3 Separation of Variables for the General Case of a Linear Second- Order Partial Differential Equation.....	37
Problems.....	39
<b>3 Heat Transfer in Pipe and Channel Flows (Parabolic Problems) .....</b>	<b>43</b>
3.1 Heat Transfer in Pipe and Channel Flows with Constant Wall Temperature .....	43
3.1.1 Velocity Distribution of Hydrodynamically Fully Developed Pipe and Channel Flows.....	44
3.1.2 Thermal Entrance Solutions for Constant Wall Temperature .....	46
Properties of the Sturm-Liouville System.....	50
3.2 Thermal Entrance Solutions for an Arbitrary Wall Temperature Distribution .....	66
3.3 Flow and Heat Transfer in Axially Rotating Pipes with Constant Wall Heat Flux .....	69
3.3.1 Velocity Distribution for the Hydrodynamically Fully Developed Flow in an Axial Rotating Pipe.....	72
3.3.2 Thermal Entrance Solution for Constant Wall Heat Flux.....	75
Problems.....	83

<b>4 Analytical Solutions for Sturm - Liouville Systems with Large Eigenvalues .....</b>	<b>87</b>
4.1 Heat Transfer in Turbulent Pipe Flow with Constant Wall Temperature .....	103
4.2 Heat Transfer in an Axially Rotating Pipe with Constant Wall Temperature.....	109
4.3 Asymptotic Expressions for other Thermal Boundary Conditions .....	113
Problems.....	115
<b>5 Heat Transfer in Duct Flows for Small Peclet Numbers (Elliptic Problems).....</b>	<b>117</b>
5.1 Heat Transfer for Constant Wall Temperatures for $x \leq 0$ and $x > 0$ .....	120
5.1.1 Heat Transfer in Laminar Pipe and Channel Flows for Small Peclet Numbers .....	131
5.1.2 Heat Transfer in Turbulent Pipe and Channel Flows for Small Peclet Numbers .....	138
5.2 Heat transfer for Constant Wall Heat Flux for $x \leq 0$ and $x > 0$ .....	142
5.2.1 Heat Transfer in Laminar Pipe and Channel Flows for Small Peclet Numbers .....	147
5.2.2 Heat Transfer in Turbulent Pipe and Channel Flows for Small Peclet Numbers .....	150
5.3 Results for Heating Sections with a Finite Length.....	153
5.3.1 Piecewise Constant Wall Temperature .....	154
5.3.1 Piecewise Constant Wall Heat Flux.....	157
5.4 Application of the Solution Method to Related Problems .....	159
Problems.....	161
<b>6 Nonlinear Partial Differential Equations .....</b>	<b>165</b>
6.1 The Method of Separation of Variables .....	165
6.2 Transformations Resulting in Linear Partial Differential Equations .....	172
6.3 Functional Relations Between Dependent Variables .....	174
6.3.1 Incompressible Flow over a Heated Flat Plate .....	174
6.3.2 Compressible Flow over a Flat, Heated Plate.....	177
6.4 Similarity Solutions .....	179
6.4.1 Similarity Solutions for a Transient Heat Conduction Problem.....	179
6.4.2 Similarity Solutions of the Boundary Layer Equations for Laminar Free Convection Flow on a Vertical Flat Plate.....	186
6.4.3 Similarity Solutions of the Compressible Boundary Layer Equations.....	192
Problems.....	198
<b>Appendix A: The Fully Developed Velocity Profile for Turbulent Duct Flows.....</b>	<b>203</b>
<b>Appendix B: The Fully Developed Velocity Profile in an Axially Rotating Pipe .....</b>	<b>215</b>

---

<b>Appendix C: A Numerical Solution Method for Eigenvalue Problems .....</b>	<b>227</b>
C.1 Numerical Tools.....	229
<b>Appendix D: Detailed Derivation of Certain Properties of the Method for Solving the Extended Graetz Problems.....</b>	<b>235</b>
D.1 Symmetry of the Matrix Operator $\tilde{L}$ .....	235
D.2 The Eigenfunctions Constitute a Set of Orthogonal Functions .....	236
D.3 A detailed Derivation of Eq. (5.31) and Eq. (5.61) .....	237
D.4 Simplification of the Expression for the Temperature Distribution (for Constant Wall Temperature) .....	239
D.5 Simplification of the Expression for the Temperature Distribution (for Constant Wall Heat Flux) .....	240
D.6 The Vector Norm $\ \vec{\Phi}_j\ ^2$ .....	243
<b>References .....</b>	<b>247</b>
<b>Index .....</b>	<b>257</b>

Analytical Methods for Heat Transfer and Fluid Flow  
Problems

Weigand, B.

2004, XX, 258 p., Hardcover

ISBN: 978-3-540-22247-7