
Contents

Preface	ix
Nomenclature	xi
Chapter 1. Introduction to Heat Transfer	1
1.1. Introduction	1
1.2. Definitions	1
1.2.1. Temperature field	1
1.2.2. Temperature gradient	1
1.2.3. Heat flux	2
1.3. Formulation of a heat transfer problem	3
1.3.1. Energy balance	3
1.3.2. Expression of energy flows	3
Chapter 2. Steady-State Conduction Heat Transfer	9
2.1. The heat equation	9
2.2. Unidirectional transfer.	11
2.2.1. Simple wall	11
2.2.2. Multilayer wall	13
2.2.3. Composite wall	15
2.2.4. Long hollow cylinder (tube)	16
2.2.5. Multilayer hollow cylinder	17
2.2.6. General case	18
2.2.7. Consideration of radiative transfer	19
2.3. Multi-directional transfer	20
2.3.1. Method of separation of variables	20
2.3.2. Shape coefficient method	24
2.3.3. Numerical methods	26

2.4. The fins	30
2.4.1. The bar equation	30
2.4.2. Flow extracted by a fin	32
2.4.3. Efficiency of a fin.	36
2.4.4. Electrical analogy.	38
2.4.5. Choice of fins	43
2.5. Corrected exercises	43
2.5.1. Heat supply in an air-conditioned room.	43
2.5.2. Heat losses from an oil pipeline	46
2.5.3. Critical insulation thickness	46
2.5.4. Hot wire anemometry.	47
2.5.5. Calculation of a fin	51
2.5.6. Temperature of teapot handles.	52
2.5.7. Thermal resistance of a finned tube	54
2.5.8. Heat input in a cold room	57
2.5.9. Pipe insulation.	59
2.5.10. Heat losses from a pipe	60
2.5.11. Effect of a fin and radiation on a thermocouple.	62
2.5.12. Internal heat transfer in a pipe	66
2.5.13. Buried pipes	69
2.5.14. Measurement of the thermal conductivity of a rock	71
Chapter 3. Heat Transfer by Conduction in Transient Regime	81
3.1. Unidirectional conduction in transient regime without change of state	81
3.1.1. Uniform temperature medium	81
3.1.2. Semi-infinite medium	83
3.1.3. Unidirectional transfer in limited media: plate, cylinder, sphere	93
3.1.4. Complex systems: quadrupole method	120
3.1.5. Established periodic state	128
3.1.6. Systems with temperature-dependent thermal properties	130
3.2. Multidirectional conduction in transient regime	133
3.2.1. Von Neuman's theorem	133
3.2.2. Integral transformations and separation of variables.	134
3.3. Corrected exercises	138
3.3.1. Age of the Earth: "Kelvin ambiguity" (1864)	138
3.3.2. Periodic variation of temperature in the ground	140
3.3.3. Measurement of thermal diffusivity by sinusoidal excitation	141
3.3.4. Freezing a lake	143
3.3.5. Freezing water pipes in dry ground	145
3.3.6. Freezing water pipes in wet ground	146
3.3.7. Firewall	149
3.3.8. Fire from a wooden beam	150

3.3.9. Flash method	151
3.3.10. Heat treatment of landing gear	156
3.3.11. Heat treatment of a carbon block.	157
3.3.12. Heat treatment of a thin layer.	161
3.3.13. Quenching of a ball	162
3.3.14. Brake pad heating	168
3.3.15. Hot plate method	171
3.3.16. Measurement of the thermal diffusivity of a thin plate.	176
3.3.17. Regular regime method	177
3.3.18. Hot wire modeling.	180
3.3.19. Intermittent heating of a chalet	183
3.3.20. Heat loss through the floor of a house	191
3.3.21. Periodic temperature variation in an unconditioned room	199
3.3.22. Periodic flow variation in an air-conditioned room.	202
Chapter 4. Convective Heat Transfer	205
4.1. Reminders on dimensional analysis	205
4.1.1. Fundamental dimensions	205
4.1.2. Principle of the method.	205
4.1.3. Application example	206
4.1.4. Advantages of using reduced quantities.	209
4.2. Convection without phase change	210
4.2.1. Generalities and definitions	210
4.2.2. Expression of heat flow rate	211
4.2.3. Calculation of heat flow rate in forced convection.	213
4.2.4. Calculation of heat flow rate in natural convection	220
4.3. Convection with phase change	223
4.3.1. Condensation	223
4.3.2. Boiling	227
4.4. Corrected exercises	231
4.4.1. Forced convection in and around a tube	231
4.4.2. Water flow in a heating tube	233
4.4.3. Air cooling in a duct	236
4.4.4. Permeable-dynamic insulation of a house	238
4.4.5. Convection in a chimney	241
4.4.6. Modeling natural convection in double glazing	242
4.4.7. Calculation of exchanges by convection in double glazing	249
4.4.8. Study of an electric kettle	253

Appendices	259
References	299
Index	303
Summary of Volume 2	305