
Contents

Preface	ix
Nomenclature	xi
Chapter 1. Heat Transfer by Radiation Between Surfaces	1
1.1. General: definitions	1
1.1.1. Type of radiation	1
1.1.2. Definitions	3
1.2. Laws of radiation	8
1.2.1. Lambert's law	8
1.2.2. Physical laws	10
1.3. Reciprocal radiation of several surfaces	14
1.3.1. Radiosity and lost net flux	14
1.3.2. Geometric form factor	15
1.3.3. Flux calculation	16
1.3.4. Electrical analogy	18
1.4. Emission and absorption of gases	21
1.5. Solar radiation	22
1.5.1. Introduction	22
1.5.2. Geometric aspects	23
1.5.3. Atmospheric radiation	31
1.5.4. Solar radiation on the ground	33
1.6. Corrected exercises	41
1.6.1. Solar irradiance	41
1.6.2. Transmission of radiation	42
1.6.3. Dew formation	43
1.6.4. Influence of radiation on temperature measurements	46
1.6.5. Outdoor air temperature measurement	47

1.6.6. Apparent emissivity of a groove	49
1.6.7. Thermal equilibrium of a satellite	50
1.6.8. Heating of a filament bulb	51
1.6.9. Heat transfer by radiation in a refrigerated display case	53
1.6.10. Heating of a wall by radiation	55
1.6.11. Cooling a teapot	58
1.6.12. Study of thermal comfort	63
1.6.13. Calculation of the global loss coefficient of double glazing	66
Chapter 2. Radiation Heat Transfer in Semi-transparent Media	71
2.1. General	71
2.2. Definitions	73
2.2.1. Monochromatic coefficients	73
2.2.2. Luminance and radiative heat flux vector	75
2.3. Radiation balance	79
2.3.1. Radiation balance equation	79
2.3.2. Divergence of radiative heat flux vector	83
2.3.3. Example of radiation balance: the semi-transparent wall	85
2.3.4. Integral form of the radiation balance equation or formal solution	87
2.4. Special cases	88
2.4.1. 1D non-scattering medium (with azimuthal symmetry)	88
2.4.2. Medium neither absorbent nor emissive	90
2.4.3. Optically thick medium	91
2.5. Conditions at the boundaries	94
2.5.1. Transparent boundaries	96
2.5.2. Opaque and black boundaries	96
2.5.3. Opaque boundaries, with diffuse emission and reflection	97
2.5.4. Opaque boundaries, diffuse emission, specular reflection	100
2.5.5. Semi-transparent interface	100
2.6. Example of an approximate solution: two-flux or Schuster–Schwarzschild approximation	102
2.6.1. Radiation balance	103
2.6.2. Special case of the gray medium	104
2.6.3. Special case of the gray and cold environment	105
2.7. Conduction–radiation coupling	108
2.7.1. Optically thick, gray and isotropically scattering medium	109
2.7.2. Purely scattering medium	110
2.7.3. Thin film model (low optical thickness)	112
2.7.4. Quadrupole for a non-scattering semi-transparent medium	112
2.8. Corrected exercises	113
2.8.1. Luminance of a semi-infinite medium	113
2.8.2. Measuring the temperature of an oven through a piece of glass	114

2.8.3. Radiative transfer between two opaque plates	116
2.8.4. Characterization of a cold semi-transparent medium	124
2.8.5. Characterization of a thin semi-transparent medium by flash method	128
2.8.6. Modeling the equivalent thermal conductivity of glass wool	130
2.8.7. Modeling a thermal conductivity measurement by hot plates	132
2.8.8. Calculation of the radiative properties of a plane wall.	136
Chapter 3. Introduction to Heat Exchangers	143
3.1. Double-pipe heat exchangers	143
3.1.1. General: definitions.	143
3.1.2. Expression of the exchanged heat flow rate	144
3.1.3. Efficiency of a heat exchanger.	151
3.1.4. Number of transfer units	153
3.1.5. Calculation of a heat exchanger	154
3.2. Complex bundle heat exchangers	155
3.2.1. General.	155
3.2.2. 1–2 Heat exchanger.	156
3.2.3. 2–4 Heat exchanger.	157
3.2.4. Cross flow heat exchanger	157
3.2.5. Refrigeration heat exchangers	159
3.3. Corrected exercises	162
3.3.1. Comparison of different types of heat exchangers	162
3.3.2. Calculation of a cross flow heat exchanger.	165
3.3.3. Calculation of a plate heat exchanger	167
3.3.4. Calculation of an embedded evaporator.	170
3.3.5. Sizing a condenser	172
Chapter 4. Flat Plate Solar Collectors	177
4.1. Principle	177
4.2. Global heat balance	178
4.2.1. Efficiencies of a solar collector	179
4.3. Thermal balances of the different constituents	181
4.3.1. Type 1 covered solar collector.	181
4.3.2. Type 2 covered solar collector.	186
4.3.3. Type 3 uncovered solar collector	187
4.3.4. Type 4 uncovered solar collector	189
4.3.5. Resolution method	190
4.4. Heat flow rate gained by the fluid as a function of the temperatures	191
4.4.1. Type 1 and 3 collectors.	191
4.4.2. Type 2 and 4 collectors.	193
4.5. Other characteristic quantities	198

4.5.1. Threshold radiation	198
4.5.2. Limit temperature	198
4.5.3. Pressure loss	199
4.6. Calculation method for a solar collector	200
4.6.1. Simulation of a solar collector	200
4.6.2. Simulation of a solar collector coupled to a storage	201
4.6.3. Dimensioning	202
4.6.4. Approximate calculation	202
4.7. Corrected exercises	203
4.7.1. Calculation of the loss coefficient of different types of collectors	203
4.7.2. Air heating in a solar collector	207
4.7.3. Solar water heater with covered tube collector	211
4.7.4. Collector-storage type solar water heater	215
4.7.5. Separate elements solar water heater	221
4.7.6. Collector with a cover semi-transparent to IR	223
Appendices	231
References	265
Index	269
Summary of Volume 1	273