
Contents

Preface	ix
Introduction	xv
Part 1. Thermal Diffusion	1
Chapter 1. Steady State	3
1.1. Partial differential equations of heat transfer in a solid	3
1.2. Variational method	6
1.3. Rayleigh–Ritz method	10
1.4. Finite element model	12
1.5. Finite element assembly	18
1.6. Convergence of the finite element method	20
1.7. Solution to the system of linear equations	24
1.8. Thermal bridge	24
Chapter 2. Boundary Conditions.	27
2.1. Dirichlet boundary conditions	27
2.1.1. Linear constraint technique	28
2.1.2. Mesh gluing	31
2.2. Neumann boundary conditions	32
2.3. Convection	34
2.3.1. Formulation of the convection element	34
2.3.2. Solid cube and cube with cavity subjected to convection	40
2.3.3. Refinement of the container mesh	41

2.3.4. Convection within the cavity inside the cube	44
2.3.5. Adiabatic cavity	47
Chapter 3. Transient Response	49
3.1. General formulation	49
3.2. Temporal integration	51
3.3. The capacity matrix	53
3.4. Temperature evolution in a solid with adiabatic boundaries	54
3.5. Solid immersed in a fluid	56
Chapter 4. Isoparametric Elements	59
4.1. The concept of Coons patch	59
4.2. Trilinear hexahedron	61
4.3. Two-parameter surfaces or Coons patches	63
4.4. Three-dimensional isoparametric element	67
4.5. Using fins to cool a solid	71
Part 2. Thermal Radiation	73
Chapter 5. Black Bodies	75
5.1. Planck's law	75
5.2. Stefan–Boltzmann law	78
5.3. Short waves and long waves	80
5.4. Kirchhoff's law	82
5.5. Solid angle	82
5.5.1. General procedure	82
5.5.2. Area of a spherical polygon	83
5.5.3. Calculating the solid angle of a triangle	84
5.6. The solar constant	86
5.7. View factor	86
5.8. Calculation of the view factor using the ray tracing method	88
Chapter 6. The Sun and Short Waves	95
6.1. The ellipse and its anomalies	96
6.2. Keplerian orbits	100
6.3. The position of the Sun	103
6.4. Sidereal time and hour angle	106

6.5. Position of the Sun based on latitude and time	108
6.6. Attenuation of solar radiation by the atmosphere.	110
6.6.1. Atmospheric pressure	111
6.6.2. The optical air mass	111
6.7. Calculation of solar irradiance.	112
6.7.1. Irradiance on a plane always oriented toward the Sun	112
6.7.2. Irradiance on a horizontal plane	114
6.7.3. Analemma	115
6.7.4. Energy calculation	116
6.8. Radiosity equations	120
6.9. Extended view factors	124
Chapter 7. The Earth and Long Waves	127
7.1. Longwave heat transfer	127
7.2. Three conventional surfaces	129
7.3. Cube section with a radiative cavity	131
7.4. Cube with a radiative cavity	133
Chapter 8. Mean Radiant Temperature	137
8.1. A cube and two spherical projections	137
8.2. Mollweide projection	138
8.3. Position of a point on the sphere in the Mollweide projection	140
8.4. Visualization of shortwave radiosities in the cube	142
8.5. Longwave radiation in a cube	143
8.6. Mollweide projections of the cube and cells of equal area	145
8.7. Use of the ray tracing technique.	147
8.8. Cube with five cold sides and one hot side	151
Conclusion	153
References	155
Index	161

