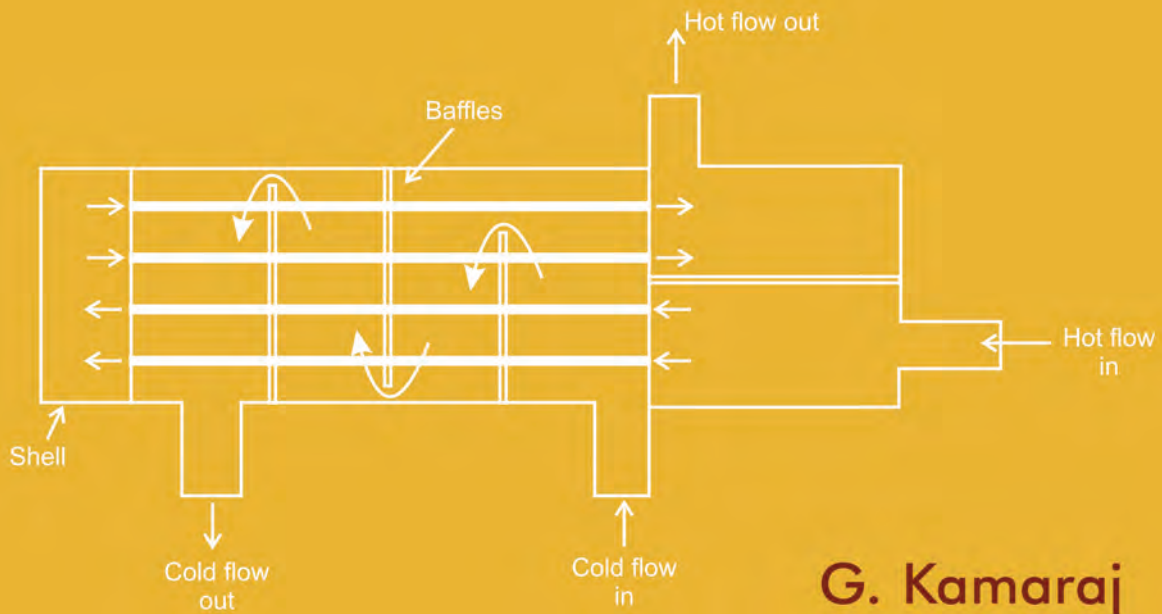
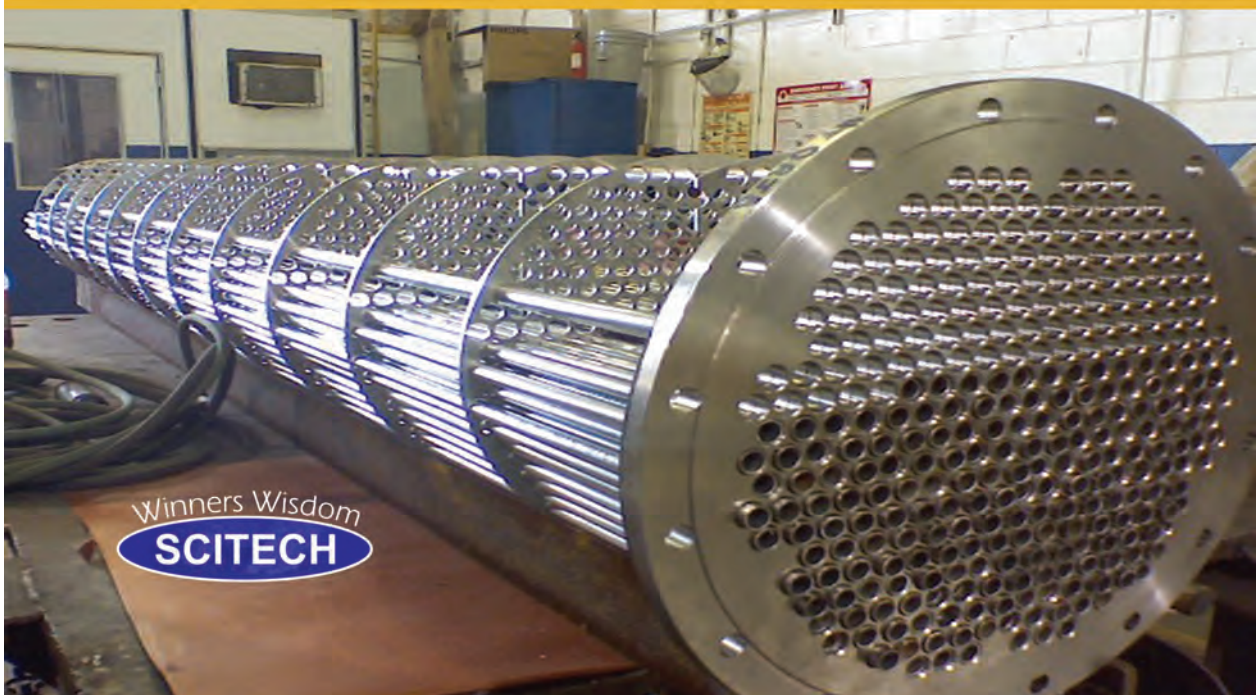


Third Edition

# Heat and Mass Transfer



**G. Kamaraj**  
**P. Raveendiran**



ISBN: 9789385983139

# HEAT AND MASS TRANSFER

Third Edition

**Dr.G. Kamaraj B.E., M.Sc (Engg)., Ph.D (IITM)**

Professor (Retd.)  
Department of Mechanical Engineering  
Annamalai University  
Annamalai Nagar - 608 002

**Dr. P. Raveendiran M.E., (Thermal Power)., Ph.D**

Assistant Professor  
Department of Mechanical Engineering  
Annamalai University  
Annamalai Nagar - 608 002



Publishing for future

**SCITECH PUBLICATIONS (INDIA) PVT. LTD.**  
**[www.scitechpublications.com](http://www.scitechpublications.com)**

[www.scitechpublications.com](http://www.scitechpublications.com)

## Contents

|                  |   |                   |
|------------------|---|-------------------|
| <b>Chapter 1</b> | <b>Basic Concepts</b>                                   | <b>1.1 - 1.14</b> |
| 1.1              | Heat Transfer - Introduction . . . . .                  | 1.1               |
| 1.1.1            | Heat . . . . .  | 1.1               |
| 1.2              | Modern Theory of Heat . . . . .                         | 1.1               |
| 1.3              | Heat Transfer in Engineering . . . . .                  | 1.2               |
| 1.3.1            | Purpose of Heat Transfer . . . . .                      | 1.2               |
| 1.4              | Thermodynamic Properties . . . . .                      | 1.2               |
| 1.4.1            | Basic Laws of Thermodynamics . . . . .                  | 1.2               |
| 1.4.2            | Thermodynamic Systems . . . . .                         | 1.2               |
| 1.4.3            | Thermodynamic Approach . . . . .                        | 1.3               |
| 1.4.4            | Thermodynamic Equilibrium . . . . .                     | 1.4               |
| 1.4.5            | Properties of System . . . . .                          | 1.4               |
| 1.4.6            | State . . . . .   | 1.4               |
| 1.4.7            | Cycle . . . . .   | 1.4               |
| 1.4.8            | Temperature . . . . .                                   | 1.5               |
| 1.4.9            | Pressure . . . . .                                      | 1.5               |
| 1.4.10           | Energy . . . . .  | 1.5               |
| 1.4.11           | Heat . . . . .  | 1.6               |
| 1.4.12           | Work . . . . .  | 1.6               |
| 1.5              | Basic Laws Governing Heat Transfer . . . . .            | 1.6               |
| 1.6              | Modes of Heat Transfer . . . . .                        | 1.8               |
| 1.6.1            | Conduction . . . . .                                    | 1.8               |
| 1.6.2            | Convection . . . . .                                    | 1.8               |
| 1.6.3            | Radiation . . . . .                                     | 1.9               |
| 1.7              | Heat Transfer by Conduction . . . . .                   | 1.9               |
| 1.7.1            | Fourier's law of Heat Conduction . . . . .              | 1.9               |
| 1.7.2            | Assumptions of Fourier's Law . . . . .                  | 1.10              |
| 1.8              | Thermal Conductivity ( $k$ ) . . . . .                  | 1.10              |
| 1.9              | Analogy Between Heat Flow and Electrical Flow . . . . . | 1.10              |
| 1.10             | Heat Flux ( $q$ ) . . . . .                             | 1.11              |
|                  | <b>Review Questions</b> . . . . .                       | <b>1.14</b>       |
|                  | <b>Unsolved Problems</b> . . . . .                      | <b>1.14</b>       |

|                  |   |                    |
|------------------|---|--------------------|
| <b>Chapter 2</b> | <b>Basic Equations to Conduction</b>  | <b>2.1 - 2.7</b>   |
| 2.1              | Introduction . . . . .  | 2.1                |
| 2.2              | General Heat Conduction Equation . . . . .  | 2.1                |
| 2.3              | Heat Conduction Equation in Cylindrical<br>Coordinate System . . . . .                      | 2.3                |
| 2.4              | Heat Conduction Equation in Spherical Coordinate System . . . . .                           | 2.6                |
|                  | <b>Review Questions</b> . . . . .   | <b>2.7</b>         |
| <b>Chapter 3</b> | <b>One Dimensional Steady State Heat Conduction</b>   | <b>3.1 - 3.105</b> |
| 3.1              | Introduction . . . . .  | 3.1                |
| 3.2              | One Dimensional Heat conduction through<br>Simple Geometrical Configurations . . . . .      | 3.1                |
| 3.2.1            | Heat conduction through a plane wall without inter-<br>nal heat generation (SLAB) . . . . . | 3.2                |
| 3.2.2            | Radial Heat Conduction Through Cylindrical Systems . . . . .                                | 3.4                |
| 3.2.3            | Radial Heat Conduction Through Spherical System . . . . .                                   | 3.6                |
| 3.2.4            | Heat conduction through a composite cylinder and<br>composite sphere . . . . .              | 3.8                |
| 3.3              | Logarithmic Mean Area for the Hollow Cylinder and Plane Wall                                | 3.10               |
| 3.4              | Logarithmic Mean Area for the Hollow sphere . . . . .                                       | 3.11               |
| 3.5              | Variable Thermal Conductivity ( $k_T$ ) . . . . .   | 3.12               |
| 3.5.1            | Effects of various Parameters on the Thermal Conduc-<br>tivity of Solids . . . . .          | 3.12               |
| 3.5.2            | Plane Wall (SLAB) with variable thermal conductivity<br>( $k_T$ ) . . . . .                 | 3.13               |
| 3.5.3            | Hollow cylinder with variable thermal conductivity ( $k_T$ )                                | 3.14               |
| 3.5.4            | Spherical system with variable thermal conductivity ( $k_T$ )                               | 3.15               |
| 3.6              | Heat Conduction Through A Composite Wall . . . . .  | 3.16               |
| 3.7              | Thermal Contact Resistance . . . . .  | 3.18               |
| 3.8              | Overall Heat-transfer Co-efficient ( $U$ ) . . . . .  | 3.19               |
| 3.9              | Series and Parallel one-dimensional heat transfer through a<br>composite wall . . . . .     | 3.20               |
| 3.10             | Critical Radius of Insulation ( $r_c$ ) . . . . .   | 3.21               |
| 3.10.1           | Critical radius of insulation for cylinder . . . . .  | 3.23               |
| 3.11             | Extended Surfaces - Fins . . . . .  | 3.24               |
| 3.11.1           | Longitudinal Fins . . . . .   | 3.24               |
| 3.11.2           | Circumferential Fins . . . . .  | 3.25               |
| 3.11.3           | Pin Fin/Spines . . . . .  | 3.25               |
| 3.11.4           | Applications of Finned Surfaces . . . . .   | 3.25               |
| 3.11.5           | Assumptions . . . . .   | 3.25               |
| 3.11.6           | Types of Fins . . . . .   | 3.26               |

|        |   |              |
|--------|---|--------------|
| 3.11.7 | Rectangular Plate Fin of Uniform Cross - Section: (Heat Flow) | 3.26         |
| 3.11.8 | Pin Fin (Spine) of uniform cross section                      | 3.29         |
| 3.11.9 | Fin-Performance   | 3.30         |
| 3.12   | Heat Conduction with Heat Generation                          | 3.32         |
| 3.12.1 | Introduction  | 3.32         |
| 3.12.2 | Plane wall with internal heat generation                      | 3.33         |
| 3.12.3 | Cylinder with internal generation                             | 3.35         |
| 3.12.4 | Sphere with internal heat generation                          | 3.37         |
|        | <b>Review Questions</b>                                       | <b>3.102</b> |
|        | <b>Unsolved Problems</b>                                      | <b>3.102</b> |

#### **Chapter 4      Multi-Dimensional Steady State Conduction      4.1 - 4.27**

|       |  |             |
|-------|--|-------------|
| 4.1   | Introduction   | 4.1         |
| 4.2   | Various Methods of Analysis Used in Multi-Dimensional (2-D) Heat Conduction              | 4.1         |
| 4.3   | Mathematical Analysis of 2-D Systems   | 4.2         |
| 4.4   | Separation of Variables Method   | 4.3         |
| 4.5   | Expression for Temperature Distribution for 2-D Heat Conduction in a Semi-Infinite Plate | 4.3         |
| 4.6   | Graphical Analysis of 2-D System (Conduction Shape Factor (S))                           | 4.5         |
| 4.7   | Numerical Relaxation Method for 2-D System   | 4.9         |
| 4.7.1 | Various Steps involved in Relaxation Process   | 4.9         |
| 4.8   | Electrical Analogy for 2-D System  | 4.10        |
| 4.9   | Three-Dimensional Steady State Conduction  | 4.11        |
| 4.9.1 | Introduction   | 4.11        |
| 4.9.2 | Various methods of analysis used in three-dimensional heat conduction                    | 4.12        |
|       | <b>Review Questions</b>  | <b>4.25</b> |
|       | <b>Unsolved Problems</b>   | <b>4.26</b> |

#### **Chapter 5      Transient Heat Conduction (Unsteady-State Conduction)      5.1 - 5.40**

|       |   |     |
|-------|---|-----|
| 5.1   | Introduction  | 5.1 |
| 5.1.1 | Transient conditions occur in                           | 5.1 |
| 5.1.2 | This transient Heat condition Problems may be solved by | 5.1 |
| 5.1.3 | Transient heat conduction can be divided into,          | 5.1 |
| 5.2   | Lumped Heat Capacity Analysis (Biot number $< 0.1$ )    | 5.2 |

|                  |   |                   |
|------------------|---|-------------------|
| 5.3              | Heat Flow in an Infinitely Thick Plate. (Semi Infinite solid)<br>( $B_i \rightarrow \infty$ or $h \rightarrow \infty$ ) . . . . . | 5.4               |
| 5.3.1            | Case (i) Constant Surface Temperature . . . . .   | 5.5               |
| 5.3.2            | Case (ii) Constant surface heat flux ( $q_o$ ) . . . . .  | 5.6               |
| 5.3.3            | Case (iii) Surface Convection . . . . .   | 5.7               |
| 5.3.4            | Biot Number ( $B_i$ ) . . . . .   | 5.7               |
| 5.3.5            | Fourier Number: ( $F_0$ ) . . . . .   | 5.8               |
| 5.4              | Transient Heat flow in Infinite Solids (Uses of Heisler Charts<br>and Grober Chart) . . . . .                                     | 5.10              |
| 5.4.1            | Infinite Plate . . . . .  | 5.10              |
| 5.4.2            | Infinite Cylinder . . . . .   | 5.12              |
| 5.4.3            | Infinite Sphere . . . . .   | 5.13              |
| 5.5              | Numerical Procedure . . . . .   | 5.23              |
|                  | <b>Review Questions</b> . . . . .   | <b>5.40</b>       |
|                  | <b>Unsolved Problems</b> . . . . .  | <b>5.40</b>       |
| <br>             |   |                   |
| <b>Chapter 6</b> | <b>Heat Transfer by Convection–Basic Concepts</b>   | <b>6.1 - 6.10</b> |
| 6.1              | Introduction . . . . .  | 6.1               |
| 6.1.1            | Ideal and real fluid . . . . .  | 6.1               |
| 6.1.2            | Free and forced convection . . . . .  | 6.2               |
| 6.1.3            | Laminar and Turbulent flow . . . . .  | 6.2               |
| 6.1.4            | Newton-Rikhman law: convection rate equation . . . . .  | 6.3               |
| 6.2              | Continuity Equation . . . . .   | 6.3               |
| 6.3              | Momentum Equation . . . . .   | 6.5               |
| 6.4              | Energy Equation . . . . .   | 6.7               |
|                  | <b>Review Questions</b> . . . . .   | <b>6.10</b>       |
| <br>             |   |                   |
| <b>Chapter 7</b> | <b>Dimensional Analysis</b>   | <b>7.1 - 7.15</b> |
| 7.1              | Introduction . . . . .  | 7.1               |
| 7.2              | Uses of Dimensional Analysis . . . . .  | 7.1               |
| 7.3              | Dimensions . . . . .  | 7.1               |
| 7.4              | Advantages and Disadvantages of Dimensional Analysis . . . . .  | 7.3               |
| 7.4.1            | Advantages . . . . .  | 7.3               |
| 7.4.2            | Disadvantages . . . . .   | 7.3               |
| 7.5              | Methods of Dimensional Analysis . . . . .   | 7.3               |
| 7.5.1            | Rayleigh’s method . . . . .   | 7.4               |
| 7.5.2            | Buckingham’s $\pi$ Theorem . . . . .  | 7.6               |
| 7.6              | Dimensional Analysis: Applied to Forced Convection:<br>$Nu = f(Re Pr)$ . . . . .  | 7.7               |

|       |  |             |
|-------|--|-------------|
| 7.7   | Dimensional Analysis applied to Free convection        |             |
|       | $Nu = f(Gr Pr)$ . . . . .                              | 7.10        |
| 7.8   | Dimensionless Numbers and their Significance . . . . . | 7.12        |
| 7.8.1 | Reynolds number ( $Re$ ) . . . . .                     | 7.12        |
| 7.8.2 | Prandtl number ( $Pr$ ) . . . . .                      | 7.12        |
| 7.8.3 | Nusselt number ( $Nu$ ) . . . . .                      | 7.13        |
| 7.8.4 | Stanton number ( $St$ ) . . . . .                      | 7.13        |
| 7.8.5 | Grashof number ( $Gr$ ) . . . . .                      | 7.13        |
| 7.8.6 | Peclet number ( $Pe$ ) . . . . .                       | 7.14        |
| 7.8.7 | Graetz number ( $G$ ) . . . . .                        | 7.14        |
| 7.9   | Newtonian Fluid and Non-Newtonian Fluid . . . . .      | 7.15        |
| 7.10  | Laminar Flow . . . . .                                 | 7.15        |
| 7.11  | Turbulent Flow . . . . .                               | 7.15        |
|       | <b>Review Questions</b> . . . . .                      | <b>7.15</b> |

|                  |  |                   |
|------------------|--|-------------------|
| <b>Chapter 8</b> | <b>Free Convection</b>   | <b>8.1 - 8.41</b> |
| 8.1              | Introduction . . . . .   | 8.1               |
| 8.2              | Momentum and Energy Equations for Laminar Free Convection        | 8.2               |
| 8.3              | Velocity and Temperature Profiles on a Vertical Flat Plate . . . | 8.3               |
| 8.4              | Empirical Correlation for Free Convection . . . . .              | 8.4               |
| 8.4.1            | For vertical plates and cylinders . . . . .                      | 8.4               |
| 8.4.2            | Horizontal plate . . . . .                                       | 8.5               |
| 8.4.3            | Horizontal cylinders . . . . .                                   | 8.5               |
| 8.4.4            | Spheres . . . . .  | 8.5               |
| 8.5              | Simplified Free Convection Equations for Air . . . . .           | 8.5               |
| 8.6              | Natural Convection from Finned Surface . . . . .                 | 8.6               |
| 8.7              | Combined Natural and Forced Convection . . . . .                 | 8.7               |
| 8.8              | Important Formulae in Free Convection . . . . .                  | 8.7               |
|                  | <b>Review Questions</b> . . . . .                                | <b>8.39</b>       |
|                  | <b>Unsolved Problems</b> . . . . .                               | <b>8.40</b>       |

|                  |   |                   |
|------------------|---|-------------------|
| <b>Chapter 9</b> | <b>Forced Convection</b>                                | <b>9.1 - 9.55</b> |
| 9.1              | Introduction . . . . .                                  | 9.1               |
| 9.2              | Laminar Flow Over a Flat Plate . . . . .                | 9.1               |
| 9.2.1            | Development of Boundary Layer on a Flat Plate . . . . . | 9.1               |
| 9.2.2            | The characteristics of a boundary layer . . . . .       | 9.2               |
| 9.3              | Boundary Layer . . . . .                                | 9.3               |
| 9.3.1            | Velocity Boundary layer . . . . .                       | 9.3               |
| 9.3.2            | Thermal Boundary layer . . . . .                        | 9.4               |
| 9.3.3            | Boundary Layer Thickness ( $\delta$ ) . . . . .         | 9.4               |



|  |  |                     |
|--|--|---------------------|
| 9.4  | Forced Convection System . . . . .   | 9.9                 |
| 9.4.1  | Introduction . . . . .   | 9.9                 |
| 9.4.2  | Flow inside a circular tube . . . . .  | 9.9                 |
| 9.4.3  | Flow inside ducts of non-circular cross-section . . . . .  | 9.10                |
| 9.4.4  | Turbulent flow inside ducts . . . . .  | 9.10                |
| 9.4.5  | Heat transfer to liquid metal . . . . .  | 9.11                |
| 9.4.6  | Heat transfer from flat surface - Formulae used in forced convection . . . . .                   | 9.12                |
|  | <b>Review Questions . . . . .</b>  | <b>9.54</b>         |
|  | <b>Unsolved Problems . . . . .</b>   | <b>9.64</b>         |
| <br><b>Chapter 10 Boiling and Condensation</b>             |  | <b>10.1 - 10.29</b> |
| 10.1   | Introduction . . . . .   | 10.1                |
|  | 10.1.1 Applications . . . . .  | 10.1                |
| 10.2   | Boiling Heat Transfer . . . . .  | 10.1                |
|  | 10.2.1 Different regimes of boiling . . . . .  | 10.3                |
|  | 10.2.2 Bubble growth and collapse . . . . .  | 10.4                |
|  | 10.2.3 Factors affecting nucleate boiling . . . . .  | 10.6                |
|  | 10.2.4 Boiling correlations . . . . .  | 10.6                |
| 10.3   | Condensation Heat Transfer . . . . .   | 10.11               |
|  | 10.3.1 Filmwise condensation . . . . .   | 10.12               |
|  | 10.3.2 Dropwise condensation . . . . .   | 10.12               |
|  | <b>Review Questions . . . . .</b>  | <b>10.28</b>        |
|  | <b>Unsolved Problems . . . . .</b>   | <b>10.29</b>        |
| <br><b>Chapter 11 Thermal Radiations - Basic Relations</b> |  | <b>11.1 - 11.18</b> |
| 11.1   | Introduction . . . . .   | 11.1                |
| 11.2   | Spectrum of Electromagnetic Radiation . . . . .  | 11.2                |
| 11.3   | Surface Emission Properties . . . . .  | 11.3                |
|  | 11.3.1 Total emissive power ( $E$ ) . . . . .  | 11.3                |
|  | 11.3.2 Monochromatic (spectral) emissive power ( $E_\lambda$ ) . . . . .                         | 11.3                |
|  | 11.3.3 Emissivity . . . . .  | 3                   |
| 11.4   | Radiation Properties of a Real Surface - Absorptivity, Reflectivity and Transmissivity . . . . . | 11.4                |
| 11.5   | Black Body . . . . .   | 11.5                |
|  | 11.5.1 Black body radiation intensity ( $I_b$ ) . . . . .  | 11.5                |
|  | 11.5.2 Spectral black body radiation intensity ( $I_{b\lambda}$ ) . . . . .                      | 11.6                |
|  | 11.5.3 Spectral black body emissive power . . . . .  | 11.6                |
|  | 11.5.4 Opaque body . . . . .   | 11.7                |
|  | 11.5.5 White body . . . . .  | 11.7                |



|        |  |              |
|--------|--|--------------|
| 11.5.6 | Gray body . . . . .                    | 11.8         |
| 11.6   | Concept of Black Body . . . . .        | 11.8         |
| 11.6.1 | Properties of a black body . . . . .   | 11.8         |
| 11.7   | Laws of Black Body Radiation . . . . . | 11.9         |
| 11.7.1 | Stefan-Boltzmann law . . . . .         | 11.9         |
| 11.7.2 | Kirchoff's law . . . . .               | 11.9         |
| 11.7.3 | Planck's law . . . . .                 | 11.10        |
| 11.7.4 | Wien's displacement law . . . . .      | 11.11        |
| 11.7.5 | Lambert's cosine law . . . . .         | 11.11        |
| 11.8   | Intensity of Radiation . . . . .       | 11.12        |
|        | <b>Review Questions</b> . . . . .      | <b>11.17</b> |
|        | <b>Unsolved Problems</b> . . . . .     | <b>11.17</b> |

## **Chapter 12 Radiation Heat Exchange between Surfaces 12.1 - 12.45**

|         |  |              |
|---------|--|--------------|
| 12.1    | Radiation Exchange between Black Bodies separated by a Non-absorbing Medium . . . . .                  | 12.1         |
| 12.1.1  | Shape or view factor . . . . .   | 12.3         |
| 12.2    | Shape Factor Relations . . . . .   | 12.3         |
| 12.2.1  | A black body inside a black body/black enclosure . . .   | 12.4         |
| 12.2.2  | A tube with cross section of an equilateral triangle . . .   | 12.4         |
| 12.2.3  | A cylindrical geometry . . . . .   | 12.5         |
| 12.2.4  | Hemispherical surface . . . . .  | 12.6         |
| 12.3    | Method of Determining Shape Factors . . . . .  | 12.7         |
| 12.4    | Radiation Heat Exchange between Black Surfaces . . . . .   | 12.10        |
| 12.5    | Radiation Heat Exchange between Non-black Bodies (Gray) . . . . .                                      | 12.11        |
| 12.5.1  | Long parallel planes . . . . .   | 12.12        |
| 12.5.2  | Long concentric cylinders . . . . .  | 12.13        |
| 12.5.3  | Concentric spheres . . . . .   | 12.13        |
| 12.6    | Radiation Heat Exchange in Three Surface Enclosures . . . . .  | 12.14        |
| 12.7    | Reradiating Surface . . . . .  | 12.16        |
| 12.8    | Radiation Between Two Non-black Surfaces (Radiation heat exchange in two surface enclosures) . . . . . | 12.17        |
| 12.9    | Radiation Shields . . . . .  | 12.29        |
| 12.10   | Radiation from Gases, Vapours and Flames . . . . .   | 12.45        |
| 12.10.1 | Mean beam length . . . . .   | 12.45        |
| 12.10.2 | Emissive Power of CO <sub>2</sub> and H <sub>2</sub> O . . . . .                                       | 12.46        |
|         | <b>Review Questions</b> . . . . .  | <b>12.47</b> |
|         | <b>Unsolved Problems</b> . . . . .   | <b>12.47</b> |

|                   |  |                     |
|-------------------|--|---------------------|
| <b>Chapter 13</b> | <b>Heat Exchangers</b>   | <b>13.1 - 13.58</b> |
| 13.1              | Introduction . . . . .   | 13.1                |
| 13.2              | Types of Heat Exchangers . . . . .   | 13.2                |
| 13.2.1            | According to heat exchanging process . . . . .                                 | 13.2                |
| 13.2.2            | According to relative direction of fluid motion . . . . .                      | 13.4                |
| 13.2.3            | Design and construction features . . . . .                                     | 13.7                |
| 13.2.4            | According to physical state of the fluid . . . . .                             | 13.8                |
| 13.3              | Overall Heat Transfer Coefficient . . . . .                                    | 13.9                |
| 13.4              | Logarithmic Mean Temperature Difference (LMTD) . . . . .                       | 13.11               |
| 13.4.1            | Assumption made on the derivation of LMTD . . . . .                            | 13.11               |
| 13.4.2            | Logarithmic mean temperature difference -<br>parallel flow . . . . .           | 13.12               |
| 13.4.3            | Logarithmic mean temperature difference of counter<br>flow . . . . .           | 13.14               |
| 13.5              | Correction for LMTD for Cross Flow and Multi pass Heat<br>Exchangers . . . . . | 13.15               |
| 13.5.1            | Rating problem . . . . .   | 13.17               |
| 13.5.2            | Effectiveness and number of transfer units (NTU) . . . . .                     | 13.19               |
| 13.5.3            | Heat exchanger effectiveness ( $\epsilon$ ) . . . . .                          | 13.19               |
|                   | <b>Review Questions</b> . . . . .  | <b>13.57</b>        |
|                   | <b>Unsolved Problems</b> . . . . .   | <b>13.58</b>        |
| <br>              |  |                     |
| <b>Chapter 14</b> | <b>Mass Transfer</b>   | <b>14.1 - 14.23</b> |
| 14.1              | Introduction . . . . .   | 14.1                |
| 14.2              | Modes of Mass Transfer . . . . .   | 14.1                |
| 14.2.1            | Mass transfer by diffusion . . . . .   | 14.2                |
| 14.3              | Concentration, Velocities and Fluxes . . . . .                                 | 14.2                |
| 14.4              | Fick's Law of Diffusion . . . . .  | 14.5                |
| 14.5              | Mass Diffusion Coefficient . . . . .   | 14.7                |
| 14.6              | Isothermal Evaporation of Water in Air from a Surface . . . . .                | 14.7                |
| 14.7              | Convective Mass Transfer . . . . .   | 14.9                |
| 14.7.1            | Convective Mass Transfer Correlations . . . . .                                | 14.10               |
| 14.7.2            | Mass Transfer Coefficient . . . . .  | 14.11               |
|                   | <b>Review Questions</b> . . . . .  | <b>14.22</b>        |
|                   | <b>Unsolved Problems</b> . . . . .   | <b>14.22</b>        |
| <br>              |  |                     |
| <b>Appendix</b>   |  | <b>A.1 - A.4</b>    |
| <b>Index</b>      |  | <b>I.1 - I.2</b>    |

# Heat and Mass Transfer

## Third Edition

This book has been prepared to meet the requirement of the undergraduate and postgraduate students of Mechanical Engineering. The book comprises of 14 chapters which cover the topics on conduction, convection, radiation and mass transfer. Number of worked out examples are included in each chapter for easy understanding of the subject. The text is supported by simple and self explanatory figures. Throughout the book S.I. Units have been followed.

**Dr. G. Kamaraj**, Professor (Retd.), Department of Mechanical Engineering at Annamalai University, has obtained his undergraduate and postgraduate degrees from Annamalai University and his Ph.D. in Heat transfer from Indian Institute of Technology, Chennai. He has a total experience of 41 years in teaching Heat and mass Transfer to U.G and P.G students. He also acted as Governing council member of Crescent Engineering College, Academic Council member of Anna University, Member, Board of studies and member doctoral committees of various Engineering Colleges. At present he is the governing council member of Solar Energy Society of India. He has to his credit 17 research publications at International level and 31 publications at National level.

**Dr. P. Raveendiran**, Assistant Professor, Department of Mechanical Engineering at Annamalai University, has obtained his undergraduate and postgraduate (Thermal Power ) degree from Annamalai University . He has obtained his **Ph.D** in the field of **Heat Transfer**, particularly in **Heat Exchanger using Heat Pipes with Nanofluids** from Annamalai University. He has a total experience of 14 years in teaching **Heat and Mass Transfer, Refrigeration and Air-Conditioning Thermodynamics and other Thermal Engineering** subjects for U.G and P.G Students. He has to his credit many research publications and also attended Many conference.



**SCITECH PUBLICATIONS (INDIA) PVT. LTD.**

[www.scitechpublications.com](http://www.scitechpublications.com)

email: [scitechcorp@yahoo.co.in](mailto:scitechcorp@yahoo.co.in)

