Course Number: 28038
Course Name: Heat Conduction

Course Type: Theoretical	Type & Max Unit: 3
Prerequisite:	Corequisite:
Level: M.Sc.	First Presentation:
Group: Energy Conversion	Last Edition:

Objectives:

Topics:

1) **Heat conduction Fundamentals**
- Definition of thermal energy (vibrational, rotational, translational modes, latent heat), temperature
- Heat conduction and its difference with heat convection.
- Heat conduction in fluids (concept of diffusion and collision) and solids (lattice waves and free electrons)
- New materials with large thermal conductivities (Graphene,…)
- Kinetic theory and conduction in ideal gases (Maxwell-Boltzmann distribution, distribution function, mean free path, mean speed, most probable speed,…)
- Analytical results for conductivity of ideal gases
- The effect of temperature on the conductivity in solids, liquids and gases
- Conductivity as a tensor and conduction in composite medium and crystals (Onsagar's principles, Keller's theorem,…)
- Conductivity of nanofluids (Maxwell's relation, Rayleigh's relation,…)
- Fourier and Non-Fourier (Physics and modeling, Cattaneo-Vernotte, Dual phase)

2) **Heat conduction equation**
- Conditions of applying first law of thermodynamics. Local thermal equilibrium concept.The shape of first law for thermal energy. General form of heat conduction equation.
- Non-Fourier heat conduction equation
- Similarity of the equations for thermal conductivity with those of scalar transport properties (permeability of porous medium, dielectric permittivity and others). Heat conduction equation in Cartesian, cylindrical and spherical coordinates. Heat conduction equation in curvilinear orthogonal coordinates.
- Types of boundary conditions (linear and nonlinear), Dirichlet, Neumann and Robin boundary conditions, interface boundary conditions: the importance and related issues in industry, friction between moving surfaces.
- Heat equation in moving solids.
- Anisotropic materials. Gradient of temperature and heat equation in this materials.
- Lumped formulations

3) **The separation of variables**

- Separability condition, The Helmholtz equation and the coordinates that the separability is possible.
- The conditions for transient and steady problems to use separation of variables.
- Numerical methods for computation of eigenvalues
- Flux formulation
- Finite and infinite medium
- Multi-dimensional problems
- Nonhomogeneous problems
- Useful transformations to reduce a differential equation into a more convenient form
- The separation of variables in the cylindrical coordinate systems
- Separation of heat equation in the spherical coordinate system (The use of Duhamel's theorem

4) The use of Duhamel's theorem

- The statement of Duhamel's theorem
- Treatment of discontinuities
- Applications of Duhamel's Theorem

5) The use of Laplace Transform

- Definition, properties, inverse, application in the solution of time-dependent heat conduction problems, approximate for small times

6) Approximate Analytic Methods

- Integral Method (Basic Concepts, Applications to Linear Transient Heat, Seminifinite problems, Nonlinear transient and finite regions
- The Galerkin Method
- Partial Integration (steady and transient problems)

7) Phase change problems

- Mathematical formulation
- exact solutions
- Integral method
- variable time-step method
- Enthalpy method

8) Moving heat source problems

- Mathematical modeling
- One dimensional quasi-stationary plane heat source problems
- Two-dimensional Quasi-Stationary Line Heat Source Problems
- Two-Dimensional Quasi-Stationary Ring Heat Source Problems

References

1. DW Hahn and MN Ozisik *Heat Conduction*, 2012, 3rd Ed.
2. VS Arpaci, *Conduction Heat Transfer*, 1966.
3. Latif. M. Jiji, Heat Conduction, 2003.
4. M. Kaviany, Heat Transfer Physics, 2008.
5. HS Carslaw and JC Jaeger, *Conduction of Heat in Solids*, 1959.
6. U Grigull and H Sandner, *Heat Conduction*, 1984.

7. JM Hill and JN Dewynne, *Heat conduction*, 1987.
8. GE Myers, Analytical methods in conduction heat transfer, 2nd Ed, 1998.
9. D Poulikakos, *Conduction Heat Transfer*, Prentice Hall 1994.
10. GE Myers, Analytical methods in Conduction Heat Transfer, 1987.
11. WH Press, SlA Teukolsky, WT Vetterling, BP Flannery, *Numerical Recipes*, 3rd Edition,2007.