MIE 1115S
HEAT TRANSFER WITH PHASE CHANGE

Winter 2021

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Description:

In this course you will learn about the phenomena that control phase change of pure substances. Most of the course will be devoted to studying liquid-vapour phase change, with an emphasis on boiling. We will study the thermodynamics of phase change, vapour bubble nucleation and growth, heat transfer during boiling, and fluid mechanics during the flow of a liquid-vapour mixture. All students are expected to have done undergraduate courses in thermodynamics, fluid mechanics and heat transfer.

Topics:

1 Introduction:
Phase change, Applications of phase change

2 Review of thermodynamics
Definitions, Postulates, Intensive and extensive parameters, Conditions for equilibrium, Gibbs-Duhem Equation, Thermodynamic potentials, Properties of a pure fluid.

3 Thermodynamic equilibrium and stability
Types of equilibrium, Energy minimum principle, Non-isolated systems, Phase transition for a pure substance, Applications.

4 Homogeneous bubble formation and growth
Size of a bubble at equilibrium, Superheat for bubble equilibrium, Bubble growth rate.

5 Bubble nucleation and growth at a surface
Nucleus formation in surface crevices, Nucleation in a temperature gradient, Bubble departure.

6 Pool boiling
Pool boiling curve, Heat transfer in pool boiling, Nucleate boiling, Film boiling, Critical heat flux, Leidenfrost phenomenon.

7 Two phase flow models and pressure drop calculations
Notation, Flow patterns, Flow pattern maps, Models for two phase flow, Homogeneous flow model, Separated flow model.

8 Flow boiling

Single phase liquid heat transfer, Nucleate and convective boiling, Critical heat flux.

9 Condensation

Homogeneous nucleation, Condensation on a vertical surface, Condensation on the surface of a horizontal tube, Condensation inside a horizontal tube, Dropwise condensation.

References:

There is no single textbook for the course. However, much of the material can be found in the books listed below. Reading assignments will be posted on the course website.

1) S. Chandra, *Energy, Entropy Engines: An Introduction to Thermodynamics*
   Available from the U of T Library at this link.

2) V.P. Carey, *Liquid-Vapor Phase-Change Phenomena*
3) J. G. Collier *Convective Boiling and Condensation*
4) P. B. Whalley *Boiling, Condensation and Gas-Liquid Flow*
5) A. Bejan *Advanced Engineering Thermodynamics*

Lectures:

Lectures will be held on-line, synchronously on Thursdays at 10:00 am EST. The first lecture will be on Thursday, Jan 14, 2021. We will use BBCollaborate for lectures.

Grading:

Mid-Term (March 4, 2021)	40%
Final	60%

Exams will be open book: you can use any references or aids but must work alone. Assignments and their solutions will be handed out, but not graded.