Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

MIE498H1: Research Thesis 2025-2026

Supervisor	Pierre Sullivan
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Number of Positions	2
Open to	Mechanical Engineering Students
Term Offered	Full-year
Research Area	Thermofluids
Research Topic	Modeling Wettability and Structured Surfaces Using Lattice Boltzmann Methods

Project Description

The intricate relationship between surface wettability and structural morphology represents a fundamental aspect of interfacial science that governs droplet dynamics and evaporation behavior across diverse applications. Structured surfaces, encompassing micro/nanostructured and patterned topographies, exert profound influence on wettability characteristics, effectively modulating contact angles from superhydrophilic states (approaching 0°) to superhydrophobic conditions (reaching 170°), which subsequently dictates evaporation kinetics through distinct modes including constant contact radius (CCR), constant contact angle (CCA), or hybrid mechanisms. The solid–liquid–vapor interface contribution on these engineered surfaces can account for up to 48% of total evaporation rates, while structural features such as micropillars induce complex contact line dynamics involving pinning and depinning phenomena that fundamentally alter mass transfer characteristics. Mixed wettability surfaces, featuring heterogeneous patterns of hydrophilic islands within hydrophobic matrices or alternating super-hydrophobic and hydrophilic stripes, demonstrate exceptional capability to enhance evaporation rates and manipulate heat transfer dynamics through droplet splitting and redistribution mechanisms. This thesis will involve developing and implementing Lattice Boltzmann (LB) models to simulate these complex wettability phenomena, leveraging the method's inherent ability to capture mesoscale physics of multiphase flows, interface dynamics, and surface interactions while accommodating arbitrary surface geometries and wettability patterns through appropriate boundary conditions and force implementations. The LB modeling approach will enable detailed investigation of contact line pinning-depinning processes, droplet shape evolution, and local flow fields within structured surfaces, providing fundamental insights into the performance of engineered surfaces in applications including spray cooling systems, precision coating applications, and inkjet printing technologies, where tailored evaporation behavior directly impacts performance efficacy and operational reliability.

Application Instructions	Please submit CV and unofficial transcript to pierre.sullivan@utoronto.ca