MechEng 714 and MATLS 715
SOLIDIFICATION PROCESSING
Course Information

INSTRUCTORS Dr. Sumanth Shankar
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SCHEDULE Term 2 Winter 2023/24: Tuesdays 9 am to 11:30 am (2.5 hours)
starts Jan19, 2022

LOCATION TBA for classroom and JHE/102 for lab

TEXT Course notes will be provided in the duration of the course.
The following textbooks were used in developing the course material

(1) W. Kurz and D.J Fischer, Fundamentals of Solidification 4th Revised Edition, Trans Tech Publications, Switzerland, 1984.
(2) M. Flemings, Solidification Processing, McGraw-Hill Inc., USA 1974
(3) D. M. Stefanescu, Science and Engineering of Casting Solidification, Second Edition, Springer, USA, 2009.
(4) Solidification and Casting, Eds. B. Cantor and K. O'Reilly, Institute of Physics Publishing, UK, 2003.
(5) M.E. Glicksman, Principles of Solidification; An Introduction to Modern Casting and Crystal Growth Concepts, Springer, USA, 2011.

and several others; **use the library**

GOALS To gain a new appreciation for the art of solidification processing (casting) through the rigors of a fundamental understanding of the science.

OBJECTIVES Upon completion of this course the student should be able to:

- Know various solidification processes (casting).
- Understand the structure of liquid metals and alloys, broadly.
- Analyze heat transport in solidification.
- Understand pure metal solidification.
- Understand alloy solidification through heat and mass transport.
- Relate solidification microstructure to process conditions.
- Evaluate solidification parameters from experiment results.
- Gain insight in numerical models for solidification
- Knowledge about defects formed during solidification.
- Appreciate recent advances in the field of near net shaped casting.

GRADING ***Tentative (subject to change with advanced notice)***
Assignments → 60%
Midterm Examination → 20%
Final Examination → 20%

Equity, Diversity, Inclusion and Accessibility

Every registered student belongs in this course. Diversity of backgrounds and experiences is expected and celebrated. You can expect your Instructor to be respectful of this diversity in all aspects of the course, and the same is expected of you.

Please feel free to discuss any matter related to Equity-Diversity-Inclusion-Accessibility with your course instructor and expect to be treated with kindness, empathy and compassion. Your instructor shall treat your personal well being as being paramount in this exercise of knowledge transfer during this course.

The Department of Mechanical Engineering is committed to creating an environment in which students of all genders, cultures, ethnicities, races, sexual orientations, abilities, and socioeconomic backgrounds have equal access to education and are welcomed and treated fairly. If you have any concerns regarding inclusion in our Department, in particular if you or one of your peers is experiencing harassment or discrimination, you are encouraged to contact the Chair, Associate Undergraduate Chair, Academic Advisor or to contact the Equity and Inclusion Office.

COURSE TOPICS (Subject to change with notice)

Topics	***Details***
Solidification Processes (Casting in today's Commerce)	Historical Perspective of Casting Length Scales DC and Continuous Casting Processes Net Shaped Casting Processes Necessity of the Variety of Processes Casting Materials and Applications Future Prospects
Liquid to Solid	Atomic Structure of Liquid Metals and Alloys Atomic Boding and Flow of Metallic Liquids Theory of Metallic Liquid State Transformation of Liquid to Solid Latent Heat of Fusion Pure and Binary Systems Introduction to Eutectics and Peritectics
Thermodynamics of Solidification	Free Energy Entropy and Reversibility Energy Balances Source Term Generation Sharp Interface Energetics (Stefan's Problem) Shrinkage and Chvorinov's Rule
Energy Transport	Heat Flow Rate of Solidification Analyze a laboratory experiment of Unidirectional solidification.
Solute Redistribution	Solid-Liquid Interface Fluid Feedability (Capillarity) Diffusion and Convection/Advection Solid/Liquid Interface Characteristics Constitutional Undercooling Stability of solidifying interface Mullins-Sekerka Stability Criterion Interface gradient and velocity relationships
Solute Redistribution	Perturbation Analyses of S/L Interface Analytical Models of Solute Redistribution
Solidification Microstructure	Growth of Perturbed Interface Ivantsov's Proposition The Mushy Zone Planar/Cellular/Dendritic Growth *Macro*segregation Solute *Micro*segregation Atomically Rough and Smooth Interface

	Growth Directionality and Morphology (Interface Surface Stiffness)
Solidification Microstructure	S/L Interface Undercooling Polyphase solidification Eutectic Solidification Peritectic Solidification Solute Trapping Rapid Solidification
Nucleation	Homogeneous Nucleation Heterogeneous Nucleation Grain Refinement In-Situ Crystallization in Melt
Solidification Defects	Dissolved Gas Pin Holes Porosity Shrinkage Hot Tear Inclusions
Fluid Dynamics	Fluid Flow during Mould Filling (Macro) Ten rules for Good Casting Micro Scale Fluid Flow Effect of Forced Convection on Microstructure Non-Dendritic Castings

ALL DIGITAL SUBMISSIONS FOR GRADING MUST ADHERE TO HIGH STANDARDS AKIN TO THAT IN NOTABLE JOURNAL PUBLICATIONS.

Each week will have a set of specific learning outcome, which shall be the focus of the weekly lectures and practice problems given to students to work on their own time. The students' efforts on the practice problems will not be graded but will certainly enhance knowledge on the topic and prove beneficial during exams.

CONDUCT EXPECTATIONS

As a McMaster graduate student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the *Code of Student Rights & Responsibilities* (the "Code"). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, **whether in person or online**.

It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery), will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students' access to these platforms.

ACADEMIC ACCOMMODATION OF STUDENTS WITH DISABILITIES

Students with disabilities who require academic accommodation must contact Student Accessibility Services (SAS) at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make arrangements with a Program Coordinator. For further information, consult McMaster University's *Academic Accommodation of Students with Disabilities* policy.

ACADEMIC ACCOMMODATION FOR RELIGIOUS, INDIGENOUS OR SPIRITUAL OBSERVANCES (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the RISO policy. Students should submit their request to their Faculty Office ***normally within 10 working days*** of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

COPYRIGHT AND RECORDING

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The

Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, **including lectures** by University instructors

The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.