ADVANCED CONCEPTS IN POLYMER EXTRUSION

Department of Chemical Engineering

CHE 773

COURSE OUTLINE

Fall Term 2025/2026

INSTRUCTOR: Dr. M. R. Thompson ABB C305 Email: mthomps@mcmaster.ca

SCHEDULE: Lectures Tuesdays 9:00-12:00, (Sept 16-Dec 14) (lecture on Sept 23rd cancelled)
Room: JHE A114 (September 12)

COURSE OBJECTIVES:

Fundamental mechanics of solids-conveying, melting, pumping and mixing. Models and practical topics in single-screw and twin-screw extrusion. Coverage of the application areas of extrusion as they exist at the present. Screw design principles, metallurgical concerns and manufacturing methods are discussed. Introduction to special topics in the field of extrusion.

PREREQUISITES: ChE 4X03/6X03 or with permission from the instructor

REQUIRED READING MATERIALS: NO TEXT BOOK REQUIRED, ELECTRONIC COURSE NOTE PROVIDED AT NO COST.

GRADING: The following table shows the contribution of components to the final grade,

Assignments (2)	50%
Report (2)	50%

The final grade percentage will be converted to letter grades using the Registrar's recommended procedure. Adjustments to the final grades may be done at the discretion of the instructor.

Due dates for graded activities:

Activity	Grade Value	Due Date*
Assignment 1	25%	Oct 7, 2025; 11:59 pm
Report 1	25%	Oct 28, 2025; 11:59 pm
Assignment 2	25%	Nov 18, 2025; 11:59 pm
Report 2	25%	Dec 9, 2025; 11:59 pm

* All activities are to be submitted through the AVENUE class portal in the appropriate activity under the menu of 'Assignments'. Assignment 1 and 2 questions are found in AVENUE.

COURSE OUTLINE:

1) Introduction to Polymer Extrusion
    a. Historical Development to Modern Interest
    b. Commercial Companies
2) Terminology
3) Select Look at Resins & Standard Operation Conditions
4) Single Screw Extrusion
    a. Areas of Application – Description, Operational Implications, and Brief Discussion of Model Theories
        i. Blown Film
        ii. Blow Molding
        iii. Cast Film
        iv. Extrusion Coating
        v. Elastomers
        vi. Fiber
        vii. Pipe & Profile
        viii. Wire & Cable
    b. Model Theory
        i. Feeding
        ii. Solids-Conveying
        iii. Melting
        iv. Melt-Conveying
        v. Mixing – Distributive / Dispersive
    c. Screw Design – Art & Science
        i. Metering Screws – Design Concepts (Styrenics)
        ii. Two-Stage Screws – Design Concepts & Model Theory
        iii. Barrier Screws – Patent History and Design Concepts
        iv. Wave Screws – Patents and Design Concepts
        v. Special Designs – ET, DSB-V
        vi. Mixers – Patent Review and Select Models
        vii. Metallurgy, Manufacturing Methods & Simple Torque Calculations
    d. Scale-Up Theory
    e. Sizing an Extruder – Bore Size, Motor HP and other considerations
    f. Auxiliary Equipment
        i. Feedstock Handling
            1. Dryers – hot air vs desicant
            2. Feeder – crammer stuffers, hopper dryers, vacuum loaders
        ii. Static Mixer
        iii. Melt Pump
        iv. Dies – Sheet, Profile, Foam, Blown Film, Blow Molding, Wire
        v. Take-Off Units (Cooling)
5) Special Topics in Single-Screw Extrusion
    a. Screw Cooling
    b. Groove-Feed Extrusion
        i. Introduction

ii. Design Considerations
iii. Models

c. Foam Extrusion
i. Introduction
ii. Theory: Cell Nucleation & Growth
iii. Equipment
1. Tandem lines
2. Screw Design
3. Die & Cooling Can

d. Starved-Feeding

6) Twin-Screw Extrusion
a. Introduction – only 10% of market share
b. Principles of Compounding
i. Degree of fill
ii. Low Pressure Generation
iii. Criteria – Low Specific Energy
c. Demand for High Torque
d. Types of Twin-Screw Extruders
i. Counter-Rotating
1. Intermeshing: Parallel & Conical – PVC
2. Modern High Speed Intermeshing (Leistritz)
3. Non-Intermeshing: Welding
ii. Co-rotating
1. Partial Intermeshing
2. Fully Intermeshing
e. Solids-Feeding
i. Gravimetric vs volumetric
ii. Side Feeders
f. Melting Theory
g. Co-Rotating, Intermeshing Screw Design
h. Mixing

7) Special Topics in Twin-Screw Extrusion
a. Reactive Extrusion
b. In-Line Compounding
c. Foam Extrusion
d. Processing Wet PET (Devolatilization)
e. Nanocomposites
f. Wood Composites
g. Rice Husk / Other Fibre Composites

SUGGESTED RESOURCES (NOT PROVIDED):

- "SPE Guide on Extrusion Technology & Troubleshooting", J. Vlachopoulos, ed., Society of Plastics Engineering Press, Connecticut, 2001
- Z. Tadmor, I. Klein, "Engineering Principles of Plasticating Extrusion", Van Nostrand Reinhold, New York, 1970

- Z. Tadmor, C. Gogos, “Principles of Polymer Processing”, Wiley-Interscience, New York, 1979
- C. Rauwendaal, “Polymer Extrusion”, Hanser Publishing, New York, 1990
- “Reactive Extrusion: Principles and Practice”, M. Xanthos, ed., Hanser Publishing, 1992
- F. G. Martelli, “Twin screw extruders : a basic understanding”, Van Nostrand Reinhold Co., New York, 1983
- L. P. B. M. Janssen, “Twin screw extrusion”, Elsevier Scientific Pub. Co., New York, 1978
- As well as selected papers from the literature.

WEBSITE: AVENUE 2 Learn

NOTES:

Report

The subject of the two reports will be discussed in class though each student is encouraged to contact the instructor to go over their individual topics once the subject has been announced. The subjects will be related to extrusion. Each report has a page limit of **15 pages** (not including title page, table of content, reference section and any appendices). *Reports exceeding this limit will be graded for only the first 15 pages and if the report appears incomplete as a result, the student will lose marks.*

Submission: Only submit a report using a current version of MS Word. Submit into either Report 1 or Report 2 listed under ‘Assignments’ in the course portal in AVENUE2Learn. The report will be automatically checked for originality by Turnitin upon submission. Turnitin takes up to 24 hours to generate its originality report, which the student will see. Re-submission is permitted up till the due date of the report. Late reports will loss 10% per day starting immediately after due date and time.

Evaluation: The report must be formatted in a manner similar to review article and will be marked on content, technical writing skill, and the ability of the author to communicate clearly and concisely. A grade will be provided on the whole report and the first two pages of content will be edited by the instructor (using Track Changes) so that technical communication skills can be improved over the span of the course.

GENERATIVE AI COMMENT – AI tools can be helpful in grammar checking a draft of a report but students must avoid using them to write the report. The purpose of writing these reports is to learn more deeply about topics related to extrusion, and to improved technical writing skills, which will not occur if the student is overly reliant on AI tools. In addition, AI tools are not well trained in technical writing, meaning what they write is usually of poor quality and will receive appropriately poor grades.

Assignments

Two assignments will be given out over the course of the term. The assignments will consist of questions on theory and practical problems. The student is expected to have access to a

computer, as some questions will involve complex and often iterative calculations. Access to Excel and MATLAB is recommended (and both are free to students).

Submission: Only submit assignments using a current version of MS Word. Submit into either Assignment 1 or Assignment 2 listed under 'Assignments' in the course portal in AVENUE2Learn. Late assignments will loss 10% per day with the first day starting immediately after the assigned time on the due date.

POLICY REMINDERS

ACADEMIC INTEGRITY

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity. ***It is your responsibility to understand what constitutes academic dishonesty.***

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university. For information on the various types of academic dishonesty please refer to the Academic Integrity Policy, located at https://secretariat.mcmaster.ca/university-policies-procedures-guidelines/

The following illustrates only three forms of academic dishonesty:
•plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
•improper collaboration in group work.
•copying or using unauthorized aids in tests and examinations.

AUTHENTICITY/PLAGIARISM DETECTION

Some courses may *use a web-based service (Turnitin.com) to reveal authenticity and ownership of student submitted work. For courses using such software, students will be expected to submit their work electronically either directly to Turnitin.com or via an online learning platform (e.g. A2L, etc.) using plagiarism detection (a service supported by Turnitin.com) so it can be checked for academic dishonesty.*

Students who do not wish their work to be submitted through the plagiarism detection software must inform the Instructor before the assignment is due. No penalty will be assigned to a student who does not submit work to the plagiarism detection software but the student must then prove they wrote the assignment/report, often by being interviewed by the instructor. ***All submitted work is subject to normal verification that standards of academic integrity have been upheld*** *(e.g., on-line search, other software, etc.). For more details about McMaster's use of Turnitin.com please go to www.mcmaster.ca/academicintegrity.*

COURSES WITH AN ON-LINE ELEMENT

Some courses may *use on-line elements (e.g. e-mail, Avenue to Learn (A2L), LearnLink, web pages, capa, Moodle, ThinkingCap, etc.). Students should be aware that, when they access the electronic components of a course using these elements, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course. The available information is dependent on the technology used. Continuation in a course that uses on-line elements will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure please discuss this with the course instructor.*

ONLINE PROCTORING

Some courses may *use online proctoring software for tests and exams. This software may require students to turn on their video camera, present identification, monitor and record their computer activities, and/or lock/restrict their browser or other applications/ software during tests or exams. This software may be required to be installed before the test/exam begins.*

CONDUCT EXPECTATIONS

As a McMaster 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.

REQUESTS FOR RELIEF FOR MISSED ACADEMIC TERM WORK

McMaster Student Absence Form (MSAF): In the event of an absence for medical or other reasons, students should review and follow the Academic Regulation in the Undergraduate Calendar "Requests for Relief for Missed Academic Term Work".

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 instructor and university reserve the right to modify elements of the course during the term. The university may change the dates and deadlines for any or all courses in extreme circumstances. If either type of modification becomes necessary, reasonable notice and communication with the students will be given with explanation and the opportunity to comment on changes. It is the responsibility of the student to check their McMaster email and course websites weekly during the term and to note any changes. Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.

POLYMER EXTRUSION

Course 773 Project

DUE DATE: Friday, November 28, 2014 6pm by email (presentation the following week after)
GRADE: 50% of final mark

The student will, based on the assigned subject in extrusion, provide a comprehensive report not exceeding a **maximum of 15 pages** (not including title page, table of content, references and any appendices). The report must be formatted in a manner similar to a thesis (refer to the Guide for the Preparation of Thesis – Graduate Studies) and will be marked on content, technical writing skill, and the ability of the author to communicate clearly and concisely. Refer to the course outline for information on lateness and any other stipulations.

SUBJECT: Chosen by the student.
SUBJECT CATEGORIES:

- ☑ Blow Molding
- ☑ Blown Film
- ☑ Cast Film
- ☑ Compounding
- ☑ Elastomers
- ☑ Extrusion Coating
- ☑ Fiber
- ☑ Pipe & Profile
- ☑ Sheet
- ☑ Wire & Cable

TOPIC: At the discretion of the student. It must have current relevance to polymer extrusion. Example topics would be microcellular foams under sheet or profile extrusion, or groove-feed extruders in pipe or wire extrusion.

COVERAGE: Under the topic as it applies to the subject given, the student should provide a report which includes: i) an introduction to the topic, ii) background of the topic giving comprehensive coverage of the literature which may include theory and any models, iii) practical consideration to operation conditions, resins, equipment, etc., iv) discussion on what is felt to be key issues on this topic based on the literature and your own opinions, and v) conclusions, if any can be drawn, and what future considerations lie ahead.

Essentially, the student is writing a review article on the topic/subject. An excellent example of a review article is given by Dr. C. Tzoganakis – C. Tzoganakis, "Reactive Extrusion of Polymers: A Review", *Adv. Polym. Technol*., **9**(4), 321 (1989)