McGill
Faculty of Engineering

Course Outline
BIEN 514

Course Title:	**Fundamentals and Rheology of Biological Fluids**
Credits:	**3**
Contact Hours:	**3-1-5**
Course Prerequisite(s):	**MATH 262, BIEN 314**
Course Description:	**Fundamentals of non-Newtonian fluid mechanics and rheology as applied to biological fluids. Fundamentals of mass and momentum conservation, dimensional analysis, continuity equations, Generalized Newtonian Fluid models, and the solution of fluid flow problems using empirical constitutive relationships. Selected topics in polymer physics relevant to biological fluids. Fundamentals of rheological characterization, both macrorheology and microrheology. Application of these concepts to the rheology of selected biological fluids in health and disease, selected applications of biofluid rheology: drug delivery, biofluid / pathogen interactions, and aerosol disease transmission.**

Canadian Engineering Accreditation Board (CEAB) Curriculum

CEAB curriculum category content	Number of AU's	Description
Math	**2**	Mathematics include appropriate elements of linear algebra, differential and integral calculus, differential equations, probability, statistics, numerical analysis, and discrete mathematics.
Natural science		Natural science includes elements of physics and chemistry, as well as life sciences and earth sciences. The subjects are intended to impart an understanding of natural phenomena and relationships through the use of analytical and/or experimental techniques.
Complementary studies		Complementary studies include the following areas of study to complement the technical content of the

		curriculum: engineering economics; the impact of technology on society; subject matter that deals with central issues, methodologies, and thought processes of the arts, humanities and social sciences; management; oral and written communications; healthy and safety; professional ethics, equity and law; and sustainable development and environmental stewardship.
Engineering science	**24**	Engineering science involves the application of mathematics and natural science to practical problems. They may involve the development of mathematical or numerical techniques, modeling, simulation, and experimental procedures. Such subjects include, among others, applied aspects of strength of materials, fluid mechanics, thermodynamics, electrical and electronic circuits, soil mechanics, automatic control, aerodynamics, transport phenomena, elements of materials science, geoscience, computer science, and environmental science.
Engineering design	**20**	Engineering design integrates mathematics, natural sciences, engineering sciences, and complementary studies in order to develop elements, systems, and processes to meet specific needs. It is a creative, iterative, and open-ended process, subject to constraints which may be governed by standards or legislation to varying degrees depending upon the discipline. These constraints may also relate to economic, health, safety, environmental, societal or other interdisciplinary factors.

Accreditation units (AU's) are defined on an hourly basis for an activity which is granted academic credit and for which the associated number of hours corresponds to the actual contact time: one hour of lecture (corresponding to 50 minutes of activity) = 1 AU; one hour of laboratory or scheduled tutorial= 0.5 AU. Classes of other than the nominal 50-minute duration are treated proportionally. In assessing the time assigned to determine the AU's of various components of the curriculum, the actual instruction time exclusive of final examinations is used.

Graduate Attributes

This course contributes to the acquisition of graduate attributes as follows:

Graduate attribute	**KB**	**PA**	**IN**	**DE**	**ET**	**IT**	**CS**	**PR**	**IE**	**EE**	**EP**	**LL**
Level descriptor	D	D	D	D	n/a	D	D	n/a	n/a	n/a	n/a	D

n/a = Not applicable; I = Introduced; D = Developed; A = Applied

KB - Knowledge Base for Engineering*: Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.*

PA - Problem Analysis*: An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.*

IN - Investigation*: An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.*

DE - Design*: An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, economic, environmental, cultural and societal considerations.*

ET - Use of Engineering Tools*: An ability to create, select, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.*

IT - Individual and Team Work*: An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.*

CS - Communication Skills*: An ability to communicate complex engineering concepts within the profession and with society at large. Such abilities include reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.*

PR - Professionalism*: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.*

IE - Impact of Engineering on Society and the Environment*: An ability to analyse social and environmental aspects of engineering activities. Such abilities include an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society; the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.*

EE - Ethics and Equity*: An ability to apply professional ethics, accountability, and equity.*

EP - Economics and Project Management*: An ability to appropriately incorporate economics and business practices including project, risk and change management into the practice of engineering, and to understand their limitations.*

LL - Life-Long Learning*: An ability to identify and to address their own educational needs in a changing world, sufficiently to maintain their competence and contribute to the advancement of knowledge.*

Department of Bioengineering
BIEN 514
Fundamentals and Rheology of Biological Fluids
Winter 2025

Instructor:
Prof. Caroline E. Wagner (caroline.wagner@mcgill.ca)
Office Location: Macdonald Engineering Building 350
Office Hours: Tuesdays, 9:00am-10:00am
Office Hours Location:
- In person: MD 350
- Virtual: https://mcgill.zoom.us/j/4615277695

Teaching Assistant:
Chukwunonso Moneme (chukwunonso.moneme@mail.mcgill.ca)

Lecture Schedule:
Tuesdays and Thursdays
Time: 11:35am-12:55pm
Location: FERR 476

Tutorial Schedule:
Tuesdays
Time: 2:35pm-3:25pm
Location: WONG 1030

Course Information:
Audience: Engineering undergraduates and early graduate students
Prerequisites: MATH 262 (or equivalent) and BIEN 314 (or equivalent fluid mechanics course) or permission of the instructor
Website: McGill myCourses will be used to distribute course materials, including lecture slides and assignments

Course Description:
Fundamentals of non-Newtonian fluid mechanics and rheology as applied to biological fluids. Fundamentals of mass and momentum conservation, dimensional analysis, continuity equations, Generalized Newtonian Fluid models, and the solution of fluid flow problems using empirical constitutive relationships. Selected topics in polymer physics relevant to biological fluids. Fundamentals of rheological characterization, both

macrorheology and microrheology. Application of these concepts to the rheology of selected biological fluids in health and disease, selected applications of biofluid rheology: drug delivery, biofluid / pathogen interactions, and aerosol disease transmission.

Course Material:

There is no required textbook for this course. Suggested texts include:

Biofluids and Fluid Mechanics:

- Roselli, R. J., and Diller, K. R. *Biotransport: principles and applications*. Springer Science & Business Media, 2011 (available as an eBook through the McGill library)

- Truskey, G. A., Yuan, F. & Katz, D. F. *Transport Phenomena in Biological Systems* (2nd Edition).

-Kundu, P., Cohen, I. & Dowling, D. *Fluid Mechanics* (4th Edition). Elsevier, 2008 (available as an eBook through the McGill library)

-Spagnolie, S. *Complex Fluids in Biological Systems*, Springer Link, 2015 (https://link.springer.com/book/10.1007/978-1-4939-2065-5)

Statistical Mechanics:

-Gould, H. & Tobochnik, J. *Thermal and Statistical Physics* (eBook available at http://stp.clarku.edu/notes/)

-Phillips, R., Kondev, J., Theriot, J., and Garcia, H. *Physical Biology of the Cell (2nd Edition),* Garland Science, 2013

Electrostatics:

-Grodzinsky, A. J. *Fields Forces and Flows in Biological Systems.* Garland Science, 2011 (available as an eBook through the McGill library)

-Phillips, R., Kondev, J., Theriot, J., and Garcia, H. *Physical Biology of the Cell (2nd Edition),* Garland Science, 2013

Polymer Physics:

-Rubinstein, M. & Colby, R. *Polymer Physics*, Oxford University Press, 2003 (available as an eBook through the McGill library)

Rheology:

-Macosko, C. W. *Rheology: Principles, Measurements, and Applications*, VCH Publishers, 1994 (available as an eBook through the McGill library)

**Additional course materials will be distributed on myCourses.

Course Objectives:

- Consolidate fundamental engineering and mathematical concepts, particularly as related to non-Newtonian fluid mechanics and rheology (KB.6)

- Apply engineering and mathematical principles to solve problems (including open-ended ones), analyze provided data, and model selected biological fluids across multiple scales. (KB.6, PA.3, IN.2, DE.1, DE.3)

- Apply these principles for the final project related to characterizing a particular biological fluid. The project will be presented to the class (DE.1, DE.3, IT.2, CS.2, CS.3)

- Actively participate in class learning through engagement in lectures and tutorials. (LL.2)

Course Grading Scheme:

Item	**Percentage**
Class Participation	5
Homework Assignments	30
Midterm Exam	30
Final Project	35

Participation: The rubric for participation grades is as follows:

Regular class attendance	3
Submission of deliverables	1
Active engagement about course material (in or out of class)	1
TOTAL (LL.2)	5

Final Project: Students will work in groups on a design project, where the fundamentals of rheology and polymer physics will be applied to understand the etiology of changes in mechanical properties of a biofluid of interest in response to a specific medical condition or environmental change. The student groups will submit a project proposal to select their topic. Then, after approval of the topic, the student groups will submit an 8-10 page report on the design project and give a 20 minute presentation highlighting the key findings and conclusions. Specific details will be given later in the course.

Grading Policies:
-**Reareads**: In accordance with
https://www.mcgill.ca/engineering/students/undergraduate/courses-registration/exams-

assessment/reread, once an assessment has been graded and returned to students, students have 10 working days (inclusive) to discuss their assessment mark breakdown with the TA or Prof. Wagner. After 10 working days, no discussions will be afforded to students. Further, no discussion on grading will be afforded to students after the last day of class of the semester.

-**Midterm**: Should a student miss the midterm exam for any reason, it will be replaced by an oral examination worth the same amount as the midterm exam.

-**Final Grades**: Note on letter grades: As permitted in the Faculty of Engineering, letter grades are assigned according to the grading scheme adopted by the professor in charge of a particular course, which may not correspond to grades indicated in the "Numerical Scale of Grades" column listed on the Grading and Grade Point Averages webpage. This is the case in this course, meaning letter grades A, A-, B+, B, etc. do not necessarily correspond to the standard 100%-85%, 84%-80%, 79%-75%, 74%-70%, etc. boundaries.

In the event of extraordinary circumstances beyond the University's control, the content and/or evaluation scheme in this course is subject to change.

Language of Written Work:

In accord with McGill University's Charter of Students' Rights, students in this course have the right to submit in English or in French any written work that is to be graded.

Academic Integrity:

McGill University values academic integrity. Therefore, all students must understand the meaning and consequences of cheating, plagiarism and other academic offences under the Code of Student Conduct and Disciplinary Procedures (see *www.mcgill.ca/students/srr/honest/* for more information).

Disabilities:

If you have a disability, please contact the instructor to arrange a time to discuss your situation. It would be helpful if you contact the Office for Students with Disabilities at (514) 398-8261 before you do this.

Copyright Statement:

Course Schedule (tentative):

Week	Date	HW/ Exams	Section	Topic
1	01/07/2025		Introduction	Introduction
	01/09/2025		Non-Newtonian Fluid Mechanics	Conservation Equations
2	01/14/2025			Dimensional Analysis
	01/16/2025			Intro to Rheology and Constitutive Relationships
3	01/21/2025	HW 1 out		Conservation Problems with non-Newtonian Fluids I
	01/23/2025			Conservation Problems with non-Newtonian Fluids II
4	01/28/2025	FPP out	Biophysics	Intro to Statistical Mechanics I
	01/30/2025			Intro to Statistical Mechanics II
5	02/04/2025	HW 1 due		Intro to Biopolymer Physics I
	02/06/2025	HW 2 out		Intro to Biopolymer Physics II
6	02/11/2025			Intro to Electrostatics I
	02/13/2025	FPP due		Intro to Electrostatics II
7	02/18/2025		Rheological Experiments	Macrorheology I: Shear Deformations 1
	02/20/2025	HW 2 due		Macrorheology II: Shear Deformations 2
8	02/25/2025			**MIDTERM EXAM**
	02/27/2025			Macrorheology III: Extensional Deformations 1
9	03/04/2025			**SPRING BREAK**
	03/06/2025			**SPRING BREAK**
10	03/11/2025			Macrorheology IV: Extensional Deformations 2
	03/13/2025	HW 3 out		Microrheology I: Single Particle Tracking 1
11	03/18/2025			Microrheology II: Single Particle Tracking 2
	03/20/2025			Microrheology III: Active Microrheology
12	03/25/2025		Biofluids and Disease	Intro to Disease Modeling and Covid 19
	03/27/2025	HW 3 due		Mucus and Disease I
13	04/01/2025			Mucus and Disease II
	04/03/2025			Mucus / Pathogen Interactions
14	04/08/2025		Presentations	**IN-CLASS PRESENTATIONS**
	04/10/2025	FP due		**IN-CLASS PRESENTATIONS**

FPP: Final Project Proposal; FP: Final Project (Written Report)