CHE241 – Introduction to Materials Science and Engineering
Department of Chemical Engineering
University of Waterloo - Fall 2022

Course content summary: Fundamentals; atomic bonding, crystalline structure, crystal defects, non-crystalline materials; structure and properties of metals, ceramics, glasses, semi-conductors. Amorphous materials, polymers, composites. Processing and concepts of engineering design of materials.

Instructor:
Franciele Turbiani
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Office hour: Wednesdays 1:00 to 2:00 pm
Skype hour: By appointment
DWE-1523

Teaching Assistant:
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Office hour: Fridays 1:30 to 2:30 pm (Microsoft Teams)
Skype hour: By appointment

You are encouraged to communicate with Franciele Turbiani (course instructor) if you have a problem that is preventing you from performing satisfactorily in this course. Do not let any issue to start affecting your learning. Take action soon!

Overall Course Objectives, you will learn about:

- material structures
- how structure dictates properties
- how processing can change structure
- how to select materials based on needs

This course will help you to:

- understand the properties materials
- use materials for engineering applications

Course Schedule:

Catalogue Section	Start Time	End Time	Meeting Days	Room
CHE241	1:30 PM	3:20 PM	Monday (Lec)	E6-2024
CHE241	9:30 AM	11:20 AM	Wednesday (Lec/Tut)	E6-2024

Homework Assignments

- Usually, due the following week.
- Late assignments will not be considered.
- Solutions will be made available after the due date.

Quizzes

- You will receive a 10 min quiz at the beginning of the tutorial session.

Tutorials

- Series of exercises to complete in 40 minutes.
- Based on previous week lecture.

Assessment:

	Scheme
Quizzes	**10 %**
Assignments	**5 %**
Midterm exam	**35 %**
Final Exam	**50 %**

Quizzes: will happen during tutorials (almost) every week.

Textbook: "Introduction to Materials Science for Engineers" 8th edition, James F. Shackelford, Prentice Hall, 2009. (7th edition is also acceptable, but students are responsible for identifying problems equivalent to 8th edition because number of pages and example problems may be different than 8th edition).

Proposed Topics: Summary of Weeks, Expected Learning Outcomes, Concept Maps…

Week	**Topics**	**Expected learning outcomes. Students should be able to…**	**CEAB**	**Suggested Examples from Textbook**
1-2	Need for materials in our society, classification of materials, areas of Materials Science and Engineering, different classifications of materials, types of materials, atomic boding, ionic bonding, coordination number, force, and energy bonding.	Tell and appraise the relevance of materials to society, needs, evolution and their historical relevance. List and categorize how materials can be classified, recall, and discuss classifications. Recognize, describe, and illustrate the chemical composition (formula and structure) of main materials. Recall, recognize, describe, and discuss main types of properties. Analyze and compare types of classifications of materials. Recall, demonstrate and appraise what Materials Science and Engineering is and its boundaries. Recall, describe and demonstrate the areas of Materials Science and Engineering. Describe and demonstrate understanding of manufacturing of translucent alumina. Recall the electronic structure of atoms and describe electron distribution in orbitals. Classify types of atomic orbitals. Define types of chemical bonding, demonstrate the energy	1, 2, 3, 5	2.1, 2.2, 2.4, 2.5, 2.8, 2.9

		and force of chemical bonds in graphics, calculate force of chemical bonds. Identify types of classification of materials based on chemical bonds, explain the influence of chemical bonding on properties of materials. Demonstrate understanding of effect of energy of chemical boding and geometry of chemical bonding on the structure of solids. Explain the effect of energy and geometry of chemical bonds in properties of materials.		
3	Crystalline structure, unit cell, crystal lattices, crystallinity in metals, ceramics and polymers, interstitial sites, crystal directions, planes, Miller indices, X-ray diffraction.	Identify and explain amorphous and crystalline arrangements of atoms in solids. Classify types of crystalline structure. Demonstrate and explain the relevance of crystalline structures in materials. Calculate packing of atoms and ions in cubic systems. Illustrate the crystalline structure of metals and ceramics in cubic systems. Demonstrate the lattice positions, directions, and planes in crystalline cubic systems. Calculate linear and planar atom densities. Explain the method for determination of crystalline structure in cubic systems. Calculate diffraction angles and spacing of atomic planes in cubic systems.	1, 2, 3, 5	3.2, 3.3, 3.6, 3.9, 3.12, 3.14, 3.15, 3.17, 3.20
4	Crystal defects; non-crystalline materials, point, line and surface defects, edge dislocation, Burgers vectors, grain boundaries, grain size number.	Identify and explain types of imperfection in crystalline structure. Demonstrate chemical and structural imperfections in metals and ceramics. Identify and calculate magnitude of defects.	1, 3, 5	4.1, 4.2, 4.4, 4.5, 4.6
5	Diffusion mechanisms in solids, thermal production of point defects, solid-state diffusion models.	Identify and explain mechanisms of diffusion in solids. Calculate the rate of diffusion and concentrations in materials. Identify and explain effect structure and temperature on diffusion and processing materials.	1, 2, 5	5.1, 5.2, 5.3, 5.4
6	Mechanical properties, stress-strain curves, modules, strength, ductility, hardness.	Identify and describe mechanical properties based on stress and strain measurements. Calculate mechanical properties of materials data from stress-strain (force-displacement). Identify and describe the effect of structure of metals, ceramics, or polymers (chemical composition, type of bonding, crystallinity, etc.) on their mechanical properties. Compare relevant mechanical properties of metals, ceramics (glasses) and polymers.	1, 2, 5	6.1, 6.2, 6.3, 6.5, 6.6

7	Deformation mechanisms, elastic and plastic deformation in metals, strengthening of metals, visco-elastic deformation in thermoplastics and elastomers.	Describe and explain the mechanisms of deformation for solid materials under mechanical load. Identify and discuss the effect of structure (chemical composition, type of bonding, crystallinity, etc.) on the deformation mechanisms of solid materials. Explain the effect of temperature on the mechanisms of deformation and mechanical properties related to deformation. Discuss the deformation behavior of solid materials and its influence in mechanical properties. Evaluate and calculate mechanical properties of solids materials related to permanent deformation.	1, 5, 9	6.7, 6.8, 6.9
8	Failure analysis, creep, fracture in metals and polymers, fracture toughness, ductile-brittle transition.	Identify and explain the mechanism of creep in materials. Calculate the creep rate in materials and explain how it is affected by temperature, stress and time. Explain and calculate stress relaxation in materials and how it is affected by temperature. Explain the mechanisms of fracture in materials and calculate fracture toughness. Describe the effect of temperature and strain rate on the fracture of materials.	1, 2, 5	6.10, 6.11, 6.12, 6.13, 8.2, 8.3
9	Thermal properties, heat capacity, coefficient of thermal expansion, correlation bonding energy and thermal properties, thermal stress, thermal shock. Midterm exam (31)	Identify and discuss the effect of temperature on the properties of materials. Explain and calculate relevant thermal properties of materials. Compare and discuss the effect of material's structure on thermal properties.	1, 2, 5	7.2, 7.3, 7.4, 7.5
10	Materials in engineering design, design parameters, materials, charts, strategies for materials selection, software CES, environmental Issues.	Identify and discuss how materials properties affect the design of products. Evaluate the importance of structure and properties of materials in engineering applications. Apply methodologies to identify and select materials based on customer needs. Describe the relevance of materials manufacturing and materials usage on the environment.	2, 4, 7, 9, 12	
11	Electronic materials, electrical conduction, energy band structures of solids, conductors, insulators, semiconductors.	Identify and discuss the mechanisms of electron conductivity in materials and correlate the mechanisms to electron configuration of atoms. Discuss and calculate the electrical properties in conductors and insulators. Explain and calculate the effect of temperature and impurities on electrical properties of materials. Explain the effect of structure on properties of semi-conductors.	1, 2, 9	

12-13	Processing and concepts of engineering design of materials, phase diagrams, phase rule, lever rule, microstructural development, kinetics, and heat Treatment.	Describe phase diagrams in materials. Calculate phase composition and phase amount in phase diagrams. Identify and describe the microstructural development in phase diagrams of metals. Discuss the effect of phase distribution in physical properties.	2, 4, 6	

CEAB Graduate Attributes:

The numbers in parentheses in the students learning objectives above refer to the CEAB Engineering Graduate Attributes defined by the Canadian Engineering Accreditation Board. These are listed below as a reference:

Outcome	Definition
1. A knowledge base for engineering	Demonstrated competence in university level mathematics, natural sciences, engineeringfundamentals, and specialized engineering knowledge appropriate to the program.
2. Problem analysis	An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solvecomplex engineering problems in order to reach substantiated conclusions.
3. 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 toreach valid conclusions.
4. 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 societalconsiderations.
5. Use of engineering tools	An ability to create, select, apply, adapt, and extend appropriate techniques, resources, andmodern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.
6. Individual and teamwork	An ability to work effectively as a member and as a leader in teams, preferably in a multi-disciplinary setting.
7.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 abilityto comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.
8. 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.
9. Impact of engineering on society and the environment	An ability to analyze social and environmental aspects of engineering activities. Such abilitiesinclude 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 andenvironmental stewardship.
10. Ethics and equity	An ability to apply professional ethics, accountability, and equity.
11. 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.
12. Life-long learning	An ability to identify and to address their own educational needs in a changing world to sufficiently maintain their competence and contribute to the advancement of knowledge.

Excerpts from University of Waterloo Policy #71 - "Student Academic Discipline Policy"
Original text available at: https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71
A university is a community of scholars in which knowledge is generated and disseminated through scholarship and teaching. All members of the community – faculty, students, and staff – are bound to conduct themselves with honesty, integrity, fairness, and concern for others. Any action which unnecessarily impedes the scholarly activities of members of the University is an offence punishable by appropriate disciplinary action.

Academic offences - Some of the academic offences outlined by the University include:
Infringing unreasonably on the work of other members of the University community (disrupting classes or examination; harassing, intimidating, or threatening others).

Cheating on examinations, assignments, work term reports, or any other work used to judge student performance. Cheating includes copying from another student's work or allowing another student to copy from one's own work, submitting another person's work as one's own, fabrication of data, consultation with an unauthorized person during an examination or test, and use of unauthorized aids.

Plagiarism, which is the act of presenting the ideas, words, or other intellectual property of another as one's own. The use of other people's work must be properly acknowledged and referenced in all written material such as take-home examinations, essays, laboratory reports, work-term reports, design projects, statistical data, computer programs and research results. The properly acknowledged use of sources is an acceptable and important part of scholarship. Use of such material without complete and unambiguous acknowledgement, however, is an offence under this policy.

Submitting an essay, report, or assignment when a major portion has been **previously submitted** or is being submitted for another course without the express permission of all instructors involved.

Classroom Protocol: Students will maintain a professional attitude in order to maintain a comfortable learning environment in the classroom and will not hamper the ability of instructor to teach and students to learn. Common examples of inappropriate behavior include, but not limited to:

- Eating in class.
- Monopolizing classroom discussions.
- Not respecting the rights of other students to express their viewpoints.
- Entering class late or leaving early.
- Usage of cell phones in the classroom (cell phones should be put in quiet/vibration mode during the lecture).
- The use of computers in class for purposes other than note taking.

Ending Note:

I would like to note that I as well as the TA of this course are here to help you. Please feel free to ask for assistance if you should require any.