MTSE 3000 – FUNDAMENTALS OF MATERIALS SCIENCE AND ENGINEERING I

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Office Hours: Tuesdays, Thursdays 3PM–4PM; or by appointment

The course will be in-person, but the Office-Hours are over Zoom.

Course Outline

The goal of the course is to introduce engineering students to the fundamental aspects of materials science and engineering and to a rigorous process of selecting materials for engineering designs. The student will be exposed to the important properties of materials, the science that governs them and the ability to choose the correct materials, taking into account the limiting design variables in a qualitative and quantitative fashion. The course also seeks to ensure that students have a broad-based knowledge of the science of all types of materials at an introductory level. The influence of costing in materials choice and its incorporation into design considerations, as well as identifying and resolving conflicting priorities, is also considered.

This course is based on the book and interactive software (Ansys/Granta EduPack) developed by Prof Mike Ashby of Cambridge University. The course combines case studies and materials science as an innovative method of teaching materials and materials selection in design. Students will have access to the software Ansys/Granta EduPack through the CENG server. We will be using this software extensively in the lectures, studies, homework and exams throughout the semester. The use of library and internet sources in self-education will also be emphasized.

Specific Course Information

Textbook: "Introduction to Materials Science and Engineering: A Design-Led Approach," M Ashby, Hugh Shercliff and David Cebon, 1st Edition, Elsevier (Butterworth-Heinemann), Cambridge, UK (2024).

Lecture Notes: Vijay K. Vasudevan on CANVAS (www.canvas.unt.edu)

Software: Granta Ansys EduPack Software (Access through CENG server)

Supplementary Book(s):

- "Materials Engineering, Science, Processing and Design," M Ashby, Hugh Shercliff and David Cebon, 4th Edition, Elsevier (Butterworth-Heinemann), Cambridge, UK (2019).
- "Materials Selection in Mechanical Design," M Ashby, 4nd Edition, Elsevier (Butterworth Heinemann), Cambridge, UK (2011).
- "Fundamentals of Materials Science and Engineering: An Integrated Approach," W.D. Callister Jr. and D.G. Rethwisch, 10th Edition, John Wiley (2020).
- "Introduction to Materials Science for Engineers," J. F. Shackleford, 9th Edition, Pearson Education Ltd (2022)

Prerequisites: PHYS 1710. CHEM 1410/CHEM 1430 or CHEM 1415/CHEM 1435.

Topics to be Covered

Topics	Chapter Sections
1. Introduction: Materials—History, Classification, and Properties	1.1–1.7 4–6, selected sections
Brief overview of materials and processes, history, type, character. Description of Mechanical properties (elastic modulus, yield/tensile strength, ductility, toughness, fracture toughness, fatigue and creep, etc.) and definition of important parameters	
2. Concept of Family Trees: Organizing Materials and Processes	1.4; 2.1–2.2
Organizing materials and processes, process-property interactions, material property charts, computer-aided information management	
3. Concepts and Process of Materials Selection in Design	2.3–2.7
The process of engineering design including concept, strategic thinking, Translation, screening, ranking, documentation and final choice of material Concept of Materials Indices and incorporation into mechanical design with cases studies. The importance of various properties in design	
4. Stiffness and Weight, Stiffness-Limited Design	3.1–3.8; 4.1–4.10 GL2-1; GL1-1
Density, elastic modulus and science behind what determines them Manipulating the modulus and density; materials indices for elastic design; plotting limits and indices on charts Bonding in materials and basics of atomic arrangement, structure and crystallography (Guided learning Unit 1) of metals, polymers, ceramics, composites, biomaterials	
5. Plasticity, Yielding, and Ductility; Strength-Limited Design	5.1–5.10
Definition of strength, plastic work and ductility, charts for yield strength Fundamental origins of strength and ductility; theoretical strength; defects, Dislocations and relation to strength; Strengthening Mechanisms; Precipitation/Dispersion Hardening; Dislocation-Precipitate Interactions; Manipulating Strength Materials indices for yield-limited design; Case studies	
6. Fracture, Fatigue and Fracture-Limited Design	6.1–6.13
Strength and toughness; Mechanics of fracture; Stress intensity and fracture toughness Origins of toughness and fracture toughness; Material property charts for toughness Manipulating strength-toughness trade-offs Material indices for fracture-safe design Characteristics of Fatigue and Fatigue Fracture Fatigue Parameters and S-N Curves; Fatigue Strength or Life; Charts for endurance limit Effect of Mean Stress on Fatigue Life; Cumulative Damage and Life Exhaustion Origins of fatigue and mechanisms; Manipulating resistance to fatigue	

8. High-Temperature Materials Behavior 8.1–8.9

Temperature dependence of material properties; Concept of diffusion and creep
Phenomenological Description of Creep; Science of Creep Mechanisms: Diffusional Creep; Dislocation Creep; Dislocation Glide Creep; Grain Boundary Sliding;
Charts for creep behavior; Materials to resist creep; Design to cope with creep

9. Degradation of Materials – Friction, Weart, Environmental 9.1–9.10

Tribological properties; physics of friction and wear; friction in design
Oxidation and oxidation mechanisms and resistance to oxidation
Corrosion: types, mechanisms and prevention/mitigation

10. Processing, Microstructure Evolution and Properties of Materials 11.1–11.12
GL 4-1

Processing for Properties; Microstructure of materials
Phase diagrams and phase transformations (guided learning Unit 4)
Microstructure evolution in processing; Heat treatment and alloying
Metals and non-metals processing

11. Functional Properties: Electrical, magnetic, electronic, semiconducting, optical, thermal properties (Follow-on course MTSE 3001 – Materials Fundamentals and Selection II) 10.1–10.15

Administrative Matters

Assignments/exams credit allocation

Attendance and In-class participation	5%
Quizzes	5%
Homework + Discussion Forum	30%
Mid-term exams (2)	40%
Final exam	20%

Final Grade Basis

A	90+
B	80-<90
C	70-<80
D	60-<70
F	<60

Class Policies

1. **Office hours:** Attending office hour sessions is entirely voluntary. It will be used for homework help and answer/clarify doubts. I will also help with any conceptual questions related to the course.

   Historically, students who ask questions during office hours (or listen to others with questions) tend to understand concepts better. This correlates well with their much better performance in the class.

2. CANVAS will be used primary for posting announcements, lecture slides, assignments and solutions.

3. Homework and exams due dates will be posted on CANVAS. Students will upload their Homework solutions on CANVAS on or before their due dates. *Emailed answers will NOT be accepted.*

4. **TA** for this class **TBD**. He/she will grade your homework and quiz assignments. Grading exams and answering class-related questions is solely my responsibility.

5. **Lectures:** Attendance is mandatory and will cover concepts and example problems. Often, I will present a problem that illustrates the theory during a lecture and encourage students to solve it on their own. I will present a discussion and solution during my office hours. The lectures will be held mostly in-class. The students will be notified if they move to Online mode in rare cases.

6. **Seven Homework Assignments:** Will involve conceptual and numerical questions.

   Homework due dates are posted on CANVAS. Late homework will get partial credits only until I post their solutions on CANVAS. I will not accept late homework after solutions are posted.

7. **Quizzes:** There will be pop quizzes and will be based on recent class lectures. Quizzes w*ill be administered in class after due announcement.* They may contain multiple choice, short answer, and/or quantitative questions/problems.

8. **Three Exams:** *Will be* **administered in class** *after due announcement.* They may contain multiple choice, short answer, and quantitative questions/problems. There will be a review prior to each exam.

   a. **Midterm Exam-01**: In the week of September 29/October 6, 2025, during your class period.

   b. **Midterm Exam-02**: In the week of November 10, 2025, during your class period.

   c. **Final Exam**: Monday, December 8, 2025 from 1:30 PM – 3:30 pm PM in the lecture hall.

   d. I will make a good effort to return your graded exams within two weeks after they are given. In rare cases, this may not happen due to other faculty related commitments.

   e. You may use only a non-programmable calculator, pencils, pens, and eraser in quizzes and exams.

   f. **Earphones, cell phones, laptops, smart watches, and other devices are banned in exams.**

Discussions Forum on CANVAS

a. You will be assigned a few materials science related videos to watch. Discuss, ask, and answer questions on materials selection in the *Discussions Forum* that I will create on CANVAS.
b. This is a team-based activity. Please self-organize into teams with three members each and email the instructor on or before August 29, 2025.
c. *Points to consider in your discussions*: (i) Identify and explain current materials need, (ii) Select a material and justify your selection; (iii) Discuss atomic bonding and structure of selected material; (iv) Present phase diagram of the selected material; (v) Predict microstructure, strengthening mechanisms, and mechanical properties; and (vi) Estimate impact on society.
d. **ANSYS Granta EduPack software must be used for this activity**. You will be instructed on how to use this software and be provided access to it.

Exam Makeup Policy

Makeup exams will be allowed only for mitigating circumstances such as business travel, serious illness of student or a close family member. A student missing her/his exam due such unavoidable situations must notify the instructor *in writing* and provide necessary documentation such as doctor's note, supervisor's note, conference talk abstract, etc. UNT student athletes must talk to the professor to discuss accommodation.

I will not allow for a makeup exam if you plan to travel before your final exams.

Authorized Absences and Extenuating Circumstances

Absences to participate in *UNT-sponsored activities* must be officially verified and approved by me. Consideration of such absences will be made for quizzes and exams, but not homework. For absences due to *extenuating circumstances*, you must contact the instructor within 1 week of such absence.

Class Attendance Policy

Class attendance is Mandatory. Please notify the instructor if you must miss a class or will be late. *Excused absences* include illness, conference travel, family emergency, religious holiday, and any other unplanned difficulty as determined by the instructor. *Unexcused absences* will invite penalty. One point per absence will be deducted from the final course grade (up to 9 absences) of students with *five or more unexcused absences. Ten or more unexcused absences* will lead to a student being dropped from the class.

Entering the class during a lecture is disruptive. Habitual latecomers will be asked to leave.

Absence for Religious Holidays

In accordance with state law, a student absent due to the observance of a religious holiday may take examinations or complete assignments scheduled for the day(s) missed, including those missed for travel, within a reasonable time after the absence. The student is responsible to notify the instructor of the date of the anticipated absence early in the semester. Only holidays or holy days observed by a religion whose place of worship is exempt from property taxation under Section

11.20 of the Tax Code may be included. A student who is excused under this provision may not be penalized for the absence.

Cell Phone Usage Policy

Cell phones and other such devices cannot be used during class for texting, online activity, electronic messaging, playing games etc. Violators of this policy will be asked to leave the class.

Specific Goals for the Course

a. Specific outcomes of instruction
b. Explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.

Specific Goals for the Course

a) Specific Course Learning Outcome
1. Relate bond energy and crystal structures to properties of engineering materials.
2. Understand properties, specifically yield strength, ultimate tensile strength, and elastic modulus from engineering plots of σ-ε . Understand mechanisms of solid solution strengthening, precipitation strengthening, strain hardening, and grain size strengthening.
3. Demonstrate ability to understand fundamentals of common phase transformations, read a phase composition-temperature diagram, including determining phase diagram type, predict phase compositions, and predict microstructures for given compositions.
4. Conduct and present a material selection survey for materials applications as a team. Exhibit awareness of societal implications associated with various materials, including specifically occupational safety and health and global availabilities of materials.

b) This course addresses *ABET Student Outcome 7* (an ability to acquire and apply new knowledge as needed, using appropriate learning strategies).

Disabilities Accommodation

UNT provides reasonable accommodation to individuals with disabilities, as defined by law – Section 504 of the 1973 Rehabilitation Act and the Americans with Disabilities Act of 1990. Contact the Office of Disability Accommodation at 940-565-4323 *during the first week of semester to learn more on this*.

Expectations for Student Conduct and Academic Integrity

The students must conduct themselves in a professional manner and be honest and ethical in their work. *Academic dishonesty such as plagiarism and cheating will NOT be tolerated.* Such dishonesty is defined as an intentional act of deception in one or more of the following, disallowed, actions:

- **Assisting** – helping another commit an act of academic dishonesty.
- **Cheating** – use or attempted use of unauthorized materials, information or study aids.
- **Fabrication** – falsification or invention of any information.
- **Plagiarism** – presenting the work or words or ideas of another person as one's own.
- **Tampering** – altering or interfering with evaluation instruments and documents.
- **AI Usage** – Using artificial intelligence (AI) tools such as ChatGPT and others.

Any student violating these *Academic dishonesty* policies will receive a **Failing course grade**. Furthermore, they will be referred to UNT honors committee for additional sanctions. Consult UNT's academic manual for relevant policies and processes. When in doubt, please ask me.

Course Evaluation

Student Perceptions of Teaching (SPOT) is the student evaluation system for UNT and allows students the ability to confidentially provide constructive feedback to improve the quality of learning in the course. Please fill out the evaluations at the end of the semester.

Syllabus Change Policy

Any changes to the syllabus (in an extraordinary situation) will be clearly communicated to the students.

Prohibition of Discrimination, Harassment, and Retaliation (Policy 16.004)

The University of North Texas (UNT) prohibits discrimination and harassment because of race, color, national origin, religion, sex, sexual orientation, gender identity, gender expression, age, disability, genetic information, veteran status, or any other characteristic protected under applicable federal or state law in its application and admission processes; educational programs and activities; employment policies, procedures, and processes; and university facilities. The University takes active measures to prevent such conduct and investigates and takes remedial action when appropriate.

Emergency Notification & Procedures

UNT uses a system called Eagle Alert to quickly notify students with critical information in the event of an emergency (i.e., severe weather, campus closing, and health and public safety emergencies like chemical spills, fires, or violence). In the event of a university closure, please refer to Canvas for contingency plans for covering course materials.

Email me on or before 12:00 noon 08/20/2025 that you have read this document to get partial credit for homework-1.

The Materials Science Tetrahedron: Video Discussion Assignments

Processing

- **The Material Science of Metal 3D Printing**
  https://www.youtube.com/watch?v=fzBRYsiyxjI

- **Anodizing Aluminum**
  https://www.youtube.com/watch?v=3ZhVOy-ytJY&list=PL0INsTTU1k2UO-2-AwomFmAs4nuZU9ht3&index=18

- **Heat Treatment -The Science of Forging**
  https://www.youtube.com/watch?v=6jQ4y0LK1kY

- **The Ingenious Design of the Aluminum Beverage Can**
  https://www.youtube.com/watch?v=hUhisi2FBuw

Structure, Properties, and Performance

- **Nitinol: The Shape Memory Effect and Superelasticity**
  https://www.youtube.com/watch?v=wI-qAxKJoSU&feature=emb_rel_end

- **Titanium - The Metal That Made The SR-71 Possible**
  https://www.youtube.com/watch?v=obcya0ze6Zo

- **Aluminum - The Material That Changed The World**
  https://www.youtube.com/watch?v=yn9qhQSMCRk

- **How NASA Reinvented The Wheel - Shape Memory Alloys**
  https://www.youtube.com/watch?v=2lv6Vs12jLc

Some Example Case Studies

1. **Stiffness-limited Design**

   a) Materials for racing yacht masts.

   b) Biomaterials for bone implants.

2. **Yield-limited Design**

   a) Elastic design—materials for springs.

   b) Plastic design—materials for pressure vessels.

3. **Fracture-safe Design**

   a) Fast fracture of an ammonia tank.

   b) Explosion of a perspex pressure window during hydrostatic testing.

4. **Creep-safe Design**

   a) Design of turbine blades.

   b) Design of pipe joints.