

MSE 2090 – Spring 2025
INTRODUCTION TO THE SCIENCE OF MATERIALS

R. G. KELLY
rgk6y@virginia.edu

Course Description: *What is this course about, anyway?*

Throughout human history, the materials available have so critically determined the quality of everyday life that historians use the dominant material to describe key periods of time: the Stone Age, Bronze Age, Iron Age, etc. These ages built upon one another; iron did not fully replace bronze, but its creation gave us more options because of its better *properties*; iron is stronger than bronze, but bronze lasts longer. The invention of aluminum alloys enabled air travel by requiring less material to withstand the forces on the structure. Thus, the engines have less work to do to move just the plane itself, so it can carry more people or cargo.

Today, over 160,000 materials exist, and we interact with a wide range of them every day without giving a second thought to how they work. Materials Science provides us with a framework to understand how materials work and how we can control the various properties that make them useful to us. It is a mash-up of physics, chemistry, and mathematics that produces the materials that enable every physical structure we use.

It's not all mai tais and shuffleboard, though. The production, use, and disposal of just five materials create >10% of ALL CO₂ generated, and the demand for them will double over the next 30 years. In addition, the raw materials needed are unequally distributed globally, leading to disparities in where the costs are borne and benefits are enjoyed.

At the end of this semester, you will be able to connect material composition (the recipe), processing (how we make it), to properties (its function) from the atomic level through the macroscopic level. You will look at the world with an awareness of the specific role specific materials play.

Most of you will NOT become materials scientists, but ALL of you will spend the rest of your life solving problems. At the end of this course, you will have learned a systematic, analytical framework for problem solving that will serve you well no matter what career path you follow. In addition, all of you will work in teams of different sizes and compositions. The goals of those teams will often be finding a solution to a problem, so you will develop the skills needed to work in teams respectfully and effectively.

Learning Objectives: *What will you be able to do by the end of this course?*

- Describe atomic and electronic structures of materials and connect them to a range of material properties
- Evaluate the impact of composition, microstructural defects, and thermo-mechanical processing on material properties
- Justify the choice of materials currently selected for a specific application as well as paths for improvement
- Identify the impact of the unequal distribution of material resources and the creation of CO₂ during their manufacture, use, and disposal on the quality of life

- Translate problem statements into well-framed questions by identifying what is to be found, what needed data are available, and what assumptions are required for solution as well as being able to identify and effectively communicate detailed path(s) to solution(s).

Course Activities - *How will we help you achieve these outcomes?*

The rhythm of course activities will be a bit different from the traditional lecture format. It will incorporate more active learning during our time together in class and less lecture. We will also use tools that will help you assess your current understanding of a topic, but with very low stakes relative to your course grade. This approach represents a bit of a change in tactics for us, so we appreciate your patience and feedback.

Class sessions for this course will be recorded. Recordings will be available only to the instructor and students enrolled in the class, including those who cannot attend the live sessions. Some find them useful for studying by revisiting specific parts of a class. Recordings will be deleted when no longer necessary. Recordings may not be reproduced, shared with those not enrolled in the class, or uploaded to other online environments. Students who are not comfortable with participating in a recorded discussion session should contact the instructor. Students in a class are prohibited from recording of any kind unless authorization is obtained from the instructor.

- Before each class
 - We will give you a question about MSE and its significance
 - Read assigned section in zybook
 - Take Reading Quiz
- Each class will follow a similar structure:
 - Admin/Warm up: Going over the four-question review of last class
 - A demonstration relevant to the topic/other learning activity (team methods, video production instruction)
 - Short lecture (20-25 min)
 - Small-group, collaborative problem solving
 - Quick reconvening at end of class as a touchpoint for next step and next class
- After each class
 - Complete problem(s) started in class (all problems will be submitted for grading at the end of the week)
 - Watch video of lecture, if desired
 - Do next “Before each class”

Course Assessment Types – *How will you and we assess your learning?*

Warm Ups (50 points, 5%) will get our brains engaged again in MSE after two or more days away from it (we know it will be difficult to be away from it for that long). Each warm up will consist of four questions that will review what was discussed in the last class. We will use Poll Everywhere for this activity. Only participation in answering the questions counts, not whether the answer is right or wrong.

Reading Assessments (100 pts, 10%) will help you check your understanding of the important concepts of MSE. These will be done on Canvas outside class and will cover the material discussed in class the week before. Preparation for these should include reading the relevant section in the Zybook and a review of your class notes.

Homework (200 pts, 20%) will help you learn to translate problem statements into well-framed questions and practice developing solutions. It will also help you better understand the concepts that we discuss in class. Homework will consist of five problems which you will have time to work on in small groups during class, but will require additional time outside class. Collaboration is an important skill to develop, and homework will help you further develop that skill.

Exams (550 pts total, 55%) will assess your level of expertise on the concepts and skills, as well as your ability to apply them to solve problems. There will be two exams during the semester and a final. Some of what you learn that is covered in the first exam will be needed in the second exam and the final, which will be cumulative, albeit with a greater emphasis on material not covered in Exams 1 and 2.

Materials Video (100 pts, 10%) will provide you the opportunity to explore the impact of materials and develop your ability to communicate to a broad audience. Groups of three students will collaborate to produce a 5-minute video describing either (a) how an advancement in materials enabled a massive change in the quality of life, or (b) an alternative method of material production or end-of-life process that would reduce the CO₂ footprint of that material. We will provide resources to make sure that the process of the videomaking is not a barrier to success.

Help Yourself and Others will provide you the opportunity to further your understanding by a range of optional activities. These include providing me feedback with what topics are still confusing or writing proposed test questions. Each week you will have the opportunity to submit online a description of what the “muddiest” point was for you in that week’s material. We will use these to structure the first mini-lecture each week to cover the most popular. Writing good test questions is an excellent way to self-assess your understanding of the subject. Believe me, it’s not easy. Note performance of assessments in this category will count as extra credit.

Resources for Success – *What resources are around to help you learn?*

Learning is hard, but you can do it. How do I know? Well, you weren’t admitted to college by winning Lotto. Fortunately, there are a lot of resources available to help you succeed. On our Canvas page, there are a number of resources, some static, some dynamic. Canvas will be our course’s information hub. From it you will be able to access the tools and information you need for the course. The most up-to-date course schedule will be there as well. It will be dynamic. You can access instructors via office hours, and you can access peers via Piazza.

I will record most sessions for this course and post those recordings on Canvas. Recordings will be available only to the instructor(s) and students enrolled in the class, including those who cannot attend the live sessions. Some have found it useful during studying to revisit parts of lectures to help them remember what was said beyond whatever notes they have. **Pro tip: listen to the lectures at 1.25x speed.** Slower than that will be painful and unnecessary; you can always back up if you miss something. Faster than 1.25x and Prof. Kelly will sound like a chipmunk. I will delete

the recordings when no longer necessary. The University policies are that recordings may not be reproduced, shared with those not enrolled in the class, or uploaded to other online environments. Students who are not comfortable with participating in a recorded discussion session should contact the instructor to request an alternate assessment activity. If you want to record audio yourself, please check in with me. I usually don't mind, but I need to be aware.

Pro tip: listen to the lectures at 1.25x speed. Slower than that will be painful and unnecessary; you can always back up if you miss something. Faster than 1.25x and Prof. Kelly will sound like a chipmunk. Old exams and their solution keys will also be posted.

Office hours are the most underused learning resource on college campuses. The instructors as well as the TA will have office hours each week. You can get help with concepts, homework problems, workload management, and the like.

Office Hours: Or by appointment via email

Prof. Kelly, Wilsdorf 328 , rgk6y@virginia.edu	TBD based on class survey
T. J. Montoya, Jesser 369 , mvr9uh@virginia.edu	TBD based on class survey

Your peers can often be even better teachers than your teachers. And teaching someone else is a great self-assessment tool on your own understanding. If you want to know something, figure out how to teach it. To encourage the free flow of assistance amongst the class, we will be using **Piazza to assist class discussion outside class**. The system is highly catered to getting you help fast and efficiently from classmates and the instruction team. Rather than emailing questions to the teaching staff, I encourage you to first post your questions on Piazza. See the Tools menu on the left side of our Canvas site.

Topics Covered – *What is the schedule for the semester?*

Topic	Please read:
How do atoms hold themselves together?	Intro and Ch 2 on Atomic Bonding
How do atoms arrange themselves in 3-D space in crystals?	Ch 3 on Crystal Structures
Why aren't crystals ever truly perfect? And that's a good thing?!	Ch 4 on Defects
How do atoms/molecules move? Or why you should use cologne or perfume sparingly.	Ch 5 on Diffusion
How do materials conduct electricity? How can the conductivity of silver be a quadrillion (10^{15}) higher than diamond?	Ch 6 on Electrical Properties
How do materials respond to mechanical forces?	Ch 7 on Mechanical Property Measurement
Why are metals so much more widely used in structures than ceramics?	Ch 8 on Strengthening in Metals Ch 9 on Fatigue and Fracture
Can we predict what kinds of microstructures will occur?	Ch 10 on Phase Diagrams
Can we control what kinds of microstructures occur, and who cares?	Ch 12 on Phase Transformations
How are polymers like and unlike metals and ceramics?	Ch 13/14 on Polymers

Logistics

There is a ton of important information concerning the course that we have collected below. Some of it is instructional “how-to’s”, some of it is policy, and some of it is advice.

Level of Required Effort to Expect

Classes include interactive problem solving, small group discussions, and short commentaries on course concepts and problem-solving strategies. Students are expected to do the assigned reading and review of prepared materials in advance. Students should expect to devote 5-6 hours per week outside of the classroom; involving 1-2 hours reading and 4-5 hours on the review of prepared materials, homework, and review of materials for tests and the final exam.

Co-requisite: APMA 111

Textbook: Section-specific selection from *Materials Science and Engineering, An Introduction; 10th edition*, William D. Callister Jr. and David G. Rethwisch, Wiley Publishers via zybooks.com

1. Sign in or create an account at learn.zybooks.com
2. Enter zyBook code: VIRGINIAMSE2090KellySpring2025
3. Subscribe

Evaluation: 1,000 point basis

Grades suck, I get it. Grading is not far behind, believe me, but we need to evaluate how well you have mastered the material in terms of understanding and applying the concepts. We will evaluate the extent to which the learning objectives described above are met via the following tools.

- Warm Ups at the Start of Class: (50 points, 5%)
Questions reviewing work from last class, graded on participation only through Polls Everywhere on Canvas on your mobile device.
- Reading Quizzes (100 pts, 10%)
Two to five concept questions will be assigned each week. Reading quiz grade will be normalized to 100 points for the semester. All Reading Quizzes will be assigned in Gradescope.
- Homework (250 pts, 25%)
Two to ten numeric problems will be assigned each week. Each class we will set aside some time for you to work in a group on discussing how to solve them. The Homework grade will be normalized to 200 points. All Homeworks will be assigned via Canvas and will be graded via Gradescope.
- Exams
Multiple choice, numerical skills, and short answer. Submitted via Canvas and will be graded via Gradescope.
 - Exam I and II (250 pts each, 25% each)*

- Final Exam (350 pts), 35%
- Help Yourself and Others
 - Extra Credit may be earned via submission of Muddiest Points (10 points max for semester) and Potential Exam Questions (10 points max for semester) via TopHat (Pro tip: these will be available to all and are a great resource for studying). Other opportunities may be sprinkled through the semester.

* Students will have one week to take the exam and submit online.

IMPORTANT DATES:

Add Date: January 27

Exam 1: Due February 13*

Drop Date (w/o a “W”): January 28

Spring Break: March 8-16

Drop Date (w/ a “W”): March 10

Exam 2: April 8*

Last Day of Class: April 29

Final Exam: Due May 8

**There may be times when these due dates/times will be adjusted.*

Class Rules:

1. Use email for easy questions and to setup special appt. times. Watch for announcements, corrections on email. Skeleton of lecture Powerpoint slides put on Collab before class.
2. Please display proper decorum during class.
Examples of poor decorum: sleeping, reading the newspaper, arriving late to class, talking to neighbor during lecture, leaving during class, not being respectful of your classmates
3. Be an active participant in your problem-solving teams.
4. When you have questions, PLEASE ASK!! Whether during the mini-lecture or during problem-solving
5. When I ask questions, PLEASE ANSWER! Even if you are unsure, I will help walk you in the right direction.

Homework Assignments and Exams

1. Homework assignments are due at the time and on the date indicated. Any extenuating circumstances should be cleared through Prof. Kelly prior to the assignment due date. Technical difficulties will be dealt with on a case-by-case basis; systematic issues due to poor planning will be dealt with accordingly.
2. Except where indicated, you may work with other members of the class in solving the homework problems at the conceptual level, but copying of calculations or solutions is not acceptable (see “Honor System,” below).
3. In case of a dispute of a grade, a formal memo must be submitted along with the entire assignment. The memo must clearly explain the area of dispute and professionally make the case

for a change in grade. The entire resubmitted assignment will be regraded. **The memo must be submitted within 2 weeks of the return of the assignment.**

Computer Usage

Students are expected to use computers for the lectures, to work on and submit homeworks/reading quizzes, and exams. Computers will be used to connect to the posted course content in UVa Canvas, Discussion boards, and zybooks. Computers will be used to connect to the recorded class sessions.

IMPORTANT POLICIES AND INFORMATION

The Honor System:

Every student in this course must comply with all provisions of the UVa honor system. Our tests will be open note and open book, but you are to pledge that you have neither received nor given unauthorized aid. Your signature below the pledge affirms that you have not obtained answers from another student's exam or from discussions with other students, whether in our class or not. It will also affirm that you have not used generative AI during the exam (see below).

On homework you are to pledge that the work is your own. Your signature by this pledge indicates that while you may have discussed assigned problems with fellow students at the concept level, the calculations and answers are your own.

Alleged honor violations brought to my attention will be forwarded to the Honor Committee. If, in my judgement, it is beyond a reasonable doubt that a student has committed an honor violation, that student will immediately receive a grade of zero for the affected work, irrespective of any subsequent action taken by the Honor Committee.

Use of generative AI

Generative AI is becoming increasingly widespread, for better and worse. How to best engage with it as educators and learners is still evolving, but for now, here is our class policy:

1. We are much more concerned with you learning HOW to think and solve problems rather than the numeric answer. Thus, we have a very structured way in which we will have you submit your problem solutions to be graded.
2. A quick check of some examples showed that generative AI gives the wrong answer for MSE questions about 40% of the time, so *caveat emptor*.
3. Nonetheless, you are **NOT** allowed to use generative AI for your exams.

Illness and other absences

Because of the highly interactive nature of our class, attendance in class is critical to maximize your learning and that of your colleagues. That said, your health and that of others are far more important, so if you are ill, please stay home and email me to let me know. We can make arrangements for make-up work as necessary, although we have structured the grading to allow for one's missing some assignments. If you must miss class for other reasons, such as interviews, conferences, etc., please let me know ahead of time and we will make similar arrangements.

Student Resources for Success – *What resources are around to help you?*

Students with disabilities or learning needs

It is our goal to create a learning experience that is as accessible as possible. If you anticipate any issues related to the format, materials, or requirements of this course, please meet with Prof. Kelly outside of class so we can explore potential options. Students with disabilities may also wish to work with the Student Disability Access Center (SDAC) to discuss a range of options to removing barriers in this course, including official accommodations. We are fortunate to have an SDAC advisor, Courtney MacMasters, physically located in Engineering. You may email her at cmacmasters@virginia.edu to schedule an appointment. For general questions please visit the [SDAC website: sdac.studenthealth.virginia.edu](http://sdac.studenthealth.virginia.edu). If you have already been approved for accommodations through SDAC, please send me your accommodation letter and meet with me so we can develop an implementation plan together.

Religious accommodations

It is the University's long-standing policy and practice to reasonably accommodate students so that they do not experience an adverse academic consequence when sincerely held religious beliefs or observances conflict with academic requirements.

Students who wish to request academic accommodation for a religious observance should submit their request to me by email as far in advance as possible. Students who have questions or concerns about academic accommodations for religious observance or religious beliefs may contact the University's Office for Equal Opportunity and Civil Rights (EOCR) at UVAEOCR@virginia.edu or 434-924-3200.

Community and Identity

The [Center for Diversity in Engineering](#) (CDE) is a student space dedicated to advocating for underrepresented groups in STEM. It exists to connect students with the academic, financial, health, and community resources they need to thrive both at UVA and in the world. The CDE includes an open study area, event space, and staff members on site. Through this space, we affirm and empower equitable participation toward intercultural fluency and provide the resources necessary for students to be successful during their academic journey and future careers.

Harassment, Discrimination, and Interpersonal Violence

The University of Virginia is dedicated to providing a safe and equitable learning environment for all students. If you or someone you know has been affected by power-based personal violence, more information can be found on the UVA Sexual Violence website that describes reporting options and resources available - www.virginia.edu/sexualviolence.

The same resources and options for individuals who experience sexual misconduct are available for discrimination, harassment, and retaliation. UVA prohibits discrimination and harassment based on age, color, disability, family medical or genetic information, gender identity or expression, marital status, military status, national or ethnic origin, political affiliation, pregnancy (including childbirth and related conditions), race, religion, sex, sexual orientation, or veteran status. UVA policy also prohibits retaliation for reporting such behavior.

If you witness or are aware of someone who has experienced prohibited conduct, you are encouraged to submit a report to Just Report It (justreportit.virginia.edu) or contact EOCR, the office of Equal Opportunity and Civil Rights.

If you would prefer to disclose such conduct to a confidential resource where what you share is not reported to the University, you can turn to Counseling & Psychological Services (“CAPS”) and Women’s Center Counseling Staff and Confidential Advocates (for students of all genders).

As your professor and as a person, know that I care about you and your well-being and stand ready to provide support and resources as I can. As a faculty member, I am a responsible employee, which means that I am required by University policy and by federal law to report certain kinds of conduct that you report to me to the University's Title IX Coordinator. The Title IX Coordinator's job is to ensure that the reporting student receives the resources and support that they need, while also determining whether further action is necessary to ensure survivor safety and the safety of the University community.

Support for your career development

Engaging in your career development is an important part of your student experience. For example, presenting at a research conference, attending an interview for a job or internship, or participating in an extern/shadowing experience are not only necessary steps on your path but are also invaluable lessons in and of themselves. I wish to encourage and support you in activities related to your career development. To that end, please notify me by email as far in advance as possible to arrange for appropriate accommodations.

Student support team

You have many resources available to you when you experience academic or personal stresses. In addition to your professor, the School of Engineering and Applied Science has staff members located in Thornton Hall who you can contact to help manage academic or personal challenges. Please do not wait until the end of the semester to ask for help!

Learning

[Lisa Lampe](#), Assistant Dean for Undergraduate Affairs

[Georgina Nembhard](#), Director of Student Success

[Courtney MacMasters](#), Accessibility Specialist

Free tutoring is available for most classes.

Health and Wellbeing

[Kelly Garrett](#), Assistant Dean of Students, Student Safety and Support

Elizabeth Ramirez-Weaver, CAPS counselor*

Katie Fowler, CAPS counselor*

*You may schedule time with the CAPS counselors through [Student Health](#) (<https://www.studenthealth.virginia.edu/getting-started-caps>). When scheduling, be sure to specify that you are an Engineering student. You are also urged to use [TimelyCare](#) for either scheduled or on-demand 24/7 mental health care.