

EMA 6136 – Diffusion, Kinetics, and Transport Phenomena

Course Syllabus – Spring 2018

	Office	E-Mail	Office hours
Prof: Richard G. Hennig	154 Rhines Hall	rhennig@ufl.edu	Tue 2-3 pm
TAs: Stephen Xie	269 Rhines Hall	siexie@ufl.edu	Thu 1-3 pm
Darshan Bamney	123 Rhines Hall	darshan.bamney@ufl.edu	Thu 3-5 pm

Course Description (3 credit hours)

Physical basis, equation, and theories of diffusion, tracer, chemical, multicomponent, and multiphase diffusion in general force fields.

Prerequisites:

EMA 4125 or equivalent.

Course Objectives

Kinetics describes both the phenomenological and microscopic aspects of material behaviors. These include the initiation and evolution of processes in the approach of materials toward thermodynamic equilibrium. Kinetics is a broad technical subject that encompasses elements of energy and mass transport, solid mechanics, interfacial science, phase transition theory, and defect structures.

Class Time

Monday, Wednesday, Friday Period 4 10:40-11:30 NEB 100

Text books: (required)

Title: Diffusion in Solids: Field Theory, Solid-State Principles and Applications

Author: M. E. Glicksman

ISBN: 0471239720

Title: Phase Transformations in Metals and Alloys, Third Edition

Author: D. A. Porter, K. E. Easterling, and M. Y. Sherif

ISBN: 1420062107

Textbooks are available for purchase at the Reitz Union Bookstore and on-line sources. Supplementary reading and links to various other resources/websites are provided and updated throughout the semester.

Course Website

The course website is on the Canvas system <https://ufl.instructure.com>, where you can find the syllabus, lecture notes, homework problems, announcements, and your grades. Please check it frequently.

Lectures

Lectures are critical to success in this MS&E course. Past experience has shown that you will be able to get a better grade when regularly attending class. However, I will not require attendance. Questions are highly encouraged. It will make the class more interesting, wake up your fellow students and give me a chance to explain things better. If you do not understand something, chances are that most of the class missed that point too. If you do not ask enough

questions, I may start asking you. You are responsible for material presented in lectures, reading assignments, homework, and distributed notes.

Homework

Four homework exercises will be assigned. These homework questions are essential to your study and prepare you for the exams. Some exam questions will be adapted from homework. Homework is usually due back 10 days before the corresponding exam. The approximate homework due dates are 1/19, 2/14, 3/19, 4/11. The exact submission dates are in the e-learning assignment. The purpose of homework is to give students an opportunity to evaluate and apply their knowledge. Students may collaborate on homework; however, the actual submitted assignment must represent their own work and preparation. Please see me or the TAs during their office hours to discuss homework problems.

Homework in its entirety must be word processed. For some problems you will require a suitable math package with graphing capability, e.g., Excel, MatLab, Python. Files have to be pdf, doc, docx, or pptx. Picture files (jpg, etc.) are not accepted.

Homework needs to be submitted online on e-learning. Email is not acceptable for submission of homework. Hard copies are also not accepted.

Homework will be evaluated on the following basis:

- Excellent work: 100
- Assignment acceptable: 85
- Homework submitted (showing effort): 70
- Homework submitted no or small effort: 0
- **No late homework assignments will be accepted.**

Quizzes and Interactive Learning

We will have online quizzes covering current and recent lecture material. The quizzes will typically consist of 2 to 4 quick questions that should take about 10 minutes. The quizzes serve as feedback both for you and me.

In addition, we will use Kahoot in class to provide instant feedback about important concepts. You will need an online electronic device (smartphone, tablet, computer) for the lectures running the website tool Kahoot.

Exams

Four exams are tentatively planned. Exams usually consist of short answer questions to evaluate your familiarity with the course content and some longer problems designed to test your ability to apply concepts to new situations, i.e. to promote critical thinking. Unless otherwise informed, one sheet of prepared personal notes may be used to assist you in completing examinations. In class exams use randomized seating assignment. In some cases, open-book or take-home exams may be given, and the students will be informed ahead of time. Exam work must be individual; collaboration is never allowed. Observations of cheating will be promptly reported by the exam proctor. Please see UF's statement on academic honesty: <https://www.dso.ufl.edu/%20sccr/process/student-conduct-honor-code>.

There is no final exam in this class. Exam dates are scheduled (changes are possible) for January 26, February 23, March 30, and April 20.

EDGE Student Submission Policy

EDGE students must submit all homework assignments electronically by the given deadlines. Exams must be received no more than four days after the in-class exam date. Please scan documents as a pdf and submit them electronically or via fax. We will use the department established proctoring for taking exams. You must follow-up and verify that exams are received in their entirety by the instructor. If problems occur, they must be reported early. No credit will be given for late submissions.

Exam Conflicts with other course exams

The official UF policy on exam conflict resolution states that when two exams conflict, the course with the higher number will take priority. There will be no exceptions to this rule.

Make-up exams

You only need 3 out of 4 exams. If you take all 4 exams then your lowest exam score will be dropped. You do not have to take the 4th exam if you are satisfied with the scores of the first three exams. There is no disadvantage or penalty for not taking one exam.

Make up exams will be provided only with the *prior approval of the instructor in accordance with university policies* (<https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx>). In general, acceptable reasons for excused absence from an exam include illness, serious family emergencies, special curricular requirements, military obligation, court-imposed legal obligations, and religious holidays. In all cases, you will be required to provide written documentation, and obtain prior instructor approval. You will not be excused from any exam without following the policy above, with no exceptions. Students not in attendance for the scheduled exam will receive a score of zero. **You must notify the instructor no less than 1 week of the scheduled exam of your intent and justification for missing the exam.** Make-up exams for excused absences as well as exam conflicts must occur within 1 week of the missed exam, and may occur before the missed exam.

Grading

Homework	15%
Online quizzes	10%
Best 3 out of 4 exams	75% (25% each)

You have two weeks after the test results are posted to resolve any questions about scores and grades. No changes to your exam grade will be made after that time.

Grading Scale

This course follows current UF grading policies for assigning grade points

Percentage	≥92	≥88	≥84	≥80	≥76	≥72	≥68	≥65	≥62	≥59	≥56	<56
Letter Grade	A	A-	B+	B	B-	C+	C	C-	D+	D	D-	E
Grade Points	4.0	3.67	3.33	3.0	2.67	2.33	2.0	1.67	1.33	1.0	0.67	0

In order to graduate, graduate students must have an overall GPA and an upper-division GPA of 3.0 or better (B or better). Note: a B- average is equivalent to a GPA of 2.67, and therefore, it does not satisfy this graduation requirement. For more information on grades and grading policies, please visit:

<http://gradcatalog.ufl.edu/content.php?catoid=5&navoid=1054#grades>.

Office Hours

Office hours are Tuesday afternoons 2:00-3:30 p.m. TA office hours Thursday afternoons from 1 to 5 pm. If you have any questions about the class or homework, please come to office hours or email me and the TA's. We will try to respond to e-mail questions as fast as possible. Important e-mail questions (minus identifying information) and answers may be posted to the class either by e-mail or on the course website for the benefit of other students.

Honesty Policy

All students admitted to the University of Florida have signed a statement of academic honesty committing themselves to be honest in all academic work and understanding that failure to comply with this commitment will result in disciplinary action. This statement is a reminder to uphold your obligation as a UF student and to be honest in all work submitted and exams taken in this course and all others.

Note that failure to comply with this commitment will result in disciplinary action compliant with the UF Student Honor Code Procedures.

See general regulations in the 2017-2018 graduate catalog section on academic integrity <http://gradcatalog.ufl.edu/content.php?catoid=11&navoid=2486>

Accommodation for Students with Disabilities

Students Requesting classroom accommodation must first register with the Dean of Students Office. That office will provide the student with documentation that he/she must provide to the course instructor when requesting accommodation.

UF Counseling Services

Resources are available on-campus for students having personal problems or lacking clear career and academic goals. The resources include:

- UF Counseling & Wellness Center, 3190 Radio Rd, 392-1575, psychological and psychiatric services.
- Career Resource Center, Reitz Union, 392-1601, career and job search services.

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Software Use

All faculty, staff and student of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Record keeping

All materials from this class that students did not pick up (graded exams, etc.) within 1 year of the end of class will be shredded on or after December 31, 2018.

Syllabus Changes

I reserve the right to make changes in the syllabus as needed. Any changes will be clearly announced on canvas and in class.

Course and Lecture Outline

Week	Dates	Topics	Book chapter
1	January 8 January 10 January 12	Phenomenological description of diffusion, Fick's first and second law, partial different equations	MEG 1 MEG 2
2	January 15 January 17 January 19	Special solutions to the diffusion equation, Boltzman-Matano analysis of interdiffusion experiments	MEG 3 MEG 4 MEG 11
3	January 22 January 24 January 26	Atomistic theory of diffusion: Random walk and Einstein's relation, diffusion mechanisms 1 st exam	MEG 12 MEG 13
4	January 29 January 31 February 2	Diffusion in alloys: Geometrical and physical correlation effects, Impurity diffusion, diffusion in dilute binary alloys	MEG 14 MEG 15
5	February 5 February 7 February 9	Diffusion with traps, Interstitial diffusion and anelasticity	MEG 16 MEG 19
6	February 12 February 14 February 16	High-diffusivity paths: Grain boundary diffusion, dislocation effects, surface diffusion	PES 2.7
7	February 19 February 21 February 23	No class 2 nd exam	
8	February 26 February 28 March 2	Diffusion in concentration gradients: General transport theory, fluxes and driving forces, Kirkendall effect, Darken equations, relationship between chemical and tracer diffusion coefficient	MEG 17 MEG 18 MEG 20
9	March 5-9	Spring Break	
10	March 12 March 14 March 16	Diffusion in ionic solids and semiconductors	MEG 20
11	March 19 March 21 March 23	Crystal Interfaces: Surface energy and surface tension, interfaces and crystal growth, grain growth	PES 3
12	March 26 March 28 March 30	Solidification: Homogeneous and heterogeneous nucleation in pure solids, growth of a pure solid	PES 4.1-2
13	April 2 April 4 April 6	Alloy solidification: Solidification of single phase alloys, eutectic and peritectic solidification 3 rd exam	PES 4.3
14	April 9 April 11 April 13	Diffusional transformations: Homogeneous and heterogeneous nucleation, precipitate growth, transformation kinetics illustrated by TTT diagrams	PES 5.1-4
15	April 16 April 18 April 20	Spinodal decomposition, eutectoid transformation, ordering transformations 4 th exam	PES 5.5.5
16	April 23 April 25	Martensitic transformations: Crystallography of martensitic transformations, Bain path for fcc to bcc transformation	PES 6

Images modified after Watson & Baxter (2007) Diffusion in solid-Earth systems. *Earth and Planetary Science Letters*, 253, 307-327.

What is partitioning? *Geochimica et Cosmochimica Acta*, 27, 12, 1209-1264. Glicksman, M. E. (2000) *Diffusion in solids: Field theory, solid state principles and applications*. Wiley, New York, 498 pp. Crank, J. (1983) *Mathematics of diffusion*, Oxford University Press, 432 pp. M. E. Glicksman, *Diffusion in Solids* – Field Theory, Solid-State Principles, and Applications, Wiley Interscience Publications (2000)Google Scholar. 10. P. G. Shewmon, *Diffusion in Solids*, 2nd ed., TMS AIME, Warrendale, PA (1989)Google Scholar. 11. D. Gupta and P. S. Ho, *Diffusion Phenomena in Thin Films and Microelectronic Materials*, Noyes Pub., Park Ridge, NJ (1988)Google Scholar. 12. H. S. Carslaw and J. C. Jaeger, *Conduction of Heat in Solids*, Oxford University Press (1959)Google Scholar.

Solid-state diffusion, or volume diffusion, is a mineral and trace element specific, temperature-dependent process that is typically slow in minerals, but can become significant at high temperatures found in the Earth's crust (Glicksman, 2000;Borg and Dienes, 2012). The presence of crystal defects, such as atomic vacancies and dislocations, will modify the diffusion characteristics of a mineral compared to a pristine crystal lattice.