MSE 855: Advanced Rate Theory and Diffusion
Spring 2020 Syllabus

LECTURE TIME & LOCATION: 3:00 – 3:56 pm MWF, 2245 Engineering Building

INSTRUCTOR INFORMATION

Dr. Jason Nicholas
Office Hours: 4:00 pm - 5:00 pm every Monday, CHEMS Conference Room, 2108 Eng. Bldg.
Consultations after class are also welcome.
Email: jdn@msu.edu Please do not send the instructor emails via D2L

COURSE OBJECTIVE: To present the physical processes, mathematical descriptions, and experimental methods involved in understanding the kinetics of diffusion, electro-migration, chemical reactions, phase transformations, microstructural evolution, and time-dependent mechanical response.

COURSE WEBSITE: https://d2l.msu.edu/d2l/home Copies of the class syllabus, lecture notes, etc. will be posted on the class website.

PREREQUISITES

MSE 851 (Graduate-level Thermodynamics of Solids)

TEXTS

Required Textbooks

Crank, J. (1975). The Mathematics of Diffusion. London, Oxford University Press.

Porter, D. A. and K. E. Easterling (1992). Phase Transformations in Metals and Alloys, 2nd ed. Boca Raton, FL, CRC Press. reprinted (i.e. corrected) 3rd ed OK

Recommended Textbooks

Barsoum, M.W. (2003). Fundamentals of Ceramics. New York, Taylor & Francis.

O'Hayre R. (2015). Materials Kinetics Fundamentals. Hoboken, N.J. Wiley.

Supplementary Texts on Reserve in the Engineering Library- Ranked by usefulness

Shewmon, P. (1989). Diffusion in Solids. 2nd Edition. Warrendale, Pa, Minerals, Metals Society

Good review of diffusion; light on motivation and modern applications

Boas, M. L. (1983). Mathematical Methods in the Physical Sciences. New York, John Wiley & Sons.

Good review of all that math you should already know

Gellings, P. J. and H. J. Bouwmeester, Eds. (2007). The CRC Handbook of Solids State Electrochemistry. Boca Raton, FL, CRC Press.

Good review of solid state electrochemistry

Jaeger, J. C. and H. S. Carslaw (1986). Conduction of Heat in Solids. New York Oxford University Press.

Contains many solutions to Fick's 2nd Law/Fourier's Law of Heat Conduction

Rahaman, M. N. (2007). Ceramic Processing. Boca Raton, FL, CRC/Taylor and Francis

Good review of sintering theory

ASSESSMENT

Activity	Weight
Office Hour Visit	2%
Class Participation	3%
Homework	10%
Academic Preparedness Exam	25%
Midterm	30%
Final Exam	30%

Percentage Course Grade	4-Point Scale Course Grade
92-100	4.0
87-92	3.5
82-87	3.0
77-82	2.5
72-77	2.0
67-72	1.5
62-67	1.0
<62	0.0
This is more generous than the official conversion at http://inquiry.princetonreview.com/leadgentemplate/GPA_popup.asp	

Office Hour Visit

Students are required to attend at least one office hour, for at least two minutes. Students are encouraged to attend an office hour visit towards the beginning of the semester so they can evaluate the usefulness of attending future office hours.

Class Participation

Students are expected to ask questions and get engaged in class activities. That helps make the learning process fun!

Academic Preparedness Exam

Students will be asked to complete an examination worth a small percentage of their grade on the background material for this course. A review of this background material will be briskly covered during the first three weeks of class. In addition to providing motivation to study the background material, the objective of this examination is to familiarize students with the exam format in a low-pressure manner.

Exams

All exams will be closed book, closed-notes. Students are allowed to bring cheat sheets that they alone produce to each of the exams. Both sides of ONE 8.5" x 11" sheet of paper is allowed for the Academic Preparedness Examination, both sides of TWO 8.5" x 11" sheets of paper are allowed for the Midterm, and both sides of THREE 8.5" x 11" sheets of paper are allowed for the Final exam. Students must also bring non-networked calculators (cell-phones and computers are not acceptable) to each exam.

Homework Partners

Homework sets will be assigned through the course of the semester. Students are required to work in groups ranging in size from 1-2 students (a single group of 3 authorized by Prof. Nicholas may be allowable). Students **are not** allowed to discuss homework problems with anyone other than their homework partner. For each homework assignment, **a single problem set must be submitted for each set of partners**. Only the names of those partners who have made a significant intellectual contribution the homework should appear on the homework.

Homework Format

Use clean, 8.5" x 11" ruled or engineering paper; begin each problem on a new page; only use one side of each page; box all final answers; number the problems on the top left line of the page; use the format (#, continued) to indicate problems continued from the preceding paper, make sure the problems are stapled (in the upper left corner) in the order in which they appear in the homework assignment. **Follow the rules of significant figures and work through each problem with the units attached to the numbers.**

Late Homework

Homework not submitted at the start of class on the homework due date is subject to a 20% penalty, with an additional 10% penalty per each additional day late. **If it's your job to turn the homework in and you are late, so is the homework.**

Homework and Exam Solution Sets

Complete homework and exam solution sets will be discussed or distributed in class.

ETHICAL CONDUCT

Engineers must behave ethically: the safety of the public depends on the competence, honesty, and integrity of engineering professionals. Any student caught engaging in unethical conduct (such as the discussion of homework problems between groups, cheating on examinations, etc.) will be prosecuted **TO THE FULL EXTENT POSSIBLE** in accordance with the rules set forth in the "All-University Policy on the Integrity of Scholarship and Grades" https://www.msu.edu/unit/ombud/RegsOrdsPolicies.html and **will receive a 0.0 on the assignment. Repeat offenders will receive a 0.0 in the course.** For your reference, plagiarism is defined as 6 or more unreferenced words in a row. Plagarism is unethical.

CLASS ATTENDENCE

Missing Class

Students are encouraged to attend every lecture. If students miss class, they are expected to get the notes from a fellow student. Notes will be posted on ANGEL prior to class, but these are only a basis for discussion.

LECTURE COURTESY

Respect for the instructor and one another is expected at all times. Please refrain from activities which may disrupt others such as talking on your cell phone during class, reading the newspaper, sleeping during class, etc. Students who disrupt class will be asked to leave. Lastly, please **ARRIVE PROMPTLY** at the start of class. Arriving late disrupts the attention of your fellow students who are busy trying to learn.

SPRING 2015, MSE 855 LECTURE SCHEDULE
44, 50 minute classes = 2220 minutes of in-class instruction = 40, 56 minute classes

Class	Topics	Reading Assignment	Homework
M 1/6	Lecture 1-Course Introduction, **THERMODYNAMICS REVIEW** Thermodynamics Laws and L.O.M.A.	O'Hayre 1-2 Barsoum 5.1-5.4	
W 1/8	Lecture 2- Ellingham Diagrams	O'Hayre 1-2 Barsoum 5.1-5.4	Homework 1 Assigned
F 1/10	Lecture 3- Phase Diagrams I	P&E 1.0-1.3.6 Barsoum 5.1-5.2, 8.1-8.7	
M 1/13	Lecture 4- Phase Diagrams II	P&E 1.3.2-1.5.7 P&E 1.7-1.8	
W 1/14	**No Class- Ni2+ Prospective Recruiting**		
F 1/17	**No Class- Ni2+ Prospective Recruiting**		
M 1/20	**No Class, No Office Hours-**MLK Day		
W 1/22	Lecture 5- Nanosize Effects on Phase Stability	O'Hayre 7.1	Homework 1 Due Homework 2 Assigned
F 1/24	Lecture 6- Point Defect Thermodynamics I	P&E 1.5.8 Barsoum 6.1-6.5	
M 1/27	Lecture 7- Point Defect Thermodynamics II	P&E 1.5.8 Barsoum 6.1-6.5, 10A	
W 1/24	Lecture 8- Point Defect Thermodynamics III	P&E 1.5.8 Barsoum 6.1-6.5, 10A	Homework 2 Due Homework 3 Assigned
F 1/31	**DIFFUSION** Lecture 9- Deriving Fick's Laws	O'Hayre 4.1-4.4.2 P&E 2.0-2.2.3 Crank 1.1-1.3	
M 2/3	Lecture 10- Tracer Diffusion into an Infinitely Long Sample	P&E 2.2.4 Crank 1.4	
W 2/5	Lecture 11- Academic Preparedness Q &A		Homework 3 Due
F 2/7	**Lecture 12-Academic Preparedness Examination on Lectures 1-8**		
M 2/10	Lecture 13- Infinite Diffusion Couple Interdiffusion	Crank 2.2.3	
W 2/12	Lecture 14- Modifying the Tracer Solution to Describe Diffusion into Finite and Semi-Finite Blocks	Crank 2.2.4, 2.4.3	Homework 4 Assigned
F 2/14	Lecture 15- Fourier Series Diffusion Solutions	Crank 2.3	
M 2/17	Lecture 16- Sample Fourier Series Problem: Lord Kelvin's Age of the Earth	Crank 6.1, 6.3	
W 2/19	Lecture 17- Laplace Transform Diffusion Solutions	Crank 2.4	Homework 4 Due

			Homework 5 Assigned
F 2/21	**No Class- CHEMS Prospective Grad Student Recruiting**		
M 2/24	Lecture 18- Sample Laplace Transform Problem: Case Hardening	Crank 2.4-2.5 P&E 2.2	
W 2/26	Lecture 19- Uphill Diffusion, The Kirkendall Effect, Diffusion Mechanisms, and Diffusion Coefficients	Crank 10.1-10.6	Homework 5 Due Homework 6 Assigned
F 2/28	Lecture 20- Extracting Concentration Dependent Diffusion Coefficients	P& E 2.3.3 Barsoum 7.5	
M 3/2	**No Class- Spring Break**, No Office Hours		
W 3/4	**No Class- Spring Break**		
F 3/6	**No Class- Spring Break**		
M 3/9	Lecture 21- How Random Walk Leads to Orderly Diffusion Profiles- Part I	O'Hayre 4.5.3	
W 3/11	Lecture 22- How Random Walk Leads to Orderly Diffusion Profiles- Part II	O'Hayre 4.5.3	
F 3/13	**No Class- CHEMS Prospective Grad Student Recruiting**		
M 3/16	**ELECTROKINETICS** Lecture 23- Bulk Controlled Electrical Transport	Barsoum 7.1-7.4 O'Hayre 4.5.4	
W 3/18	Lecture 24- Interface Controlled Electrical Transport	Barsoum 7.1-7.4	Homework 6 Due Homework 7 Assigned
F 3/20	Lecture 25- Electrochemical Devices		
M 3/23	Lecture 26- Prof Nicholas Lab Tour		
W 3/25	Lecture 27- Midterm Q & A		
F 3/27	**Lecture 28- Midterm on Lectures 9-22**		
M 3/30	**CHEMICAL REACTION KINETICS** Lecture 29- Introduction to Chemical Reaction Kinetics I	O'Hayre 3.1-3.6	
W 4/1	Lecture 30- Introduction to Chemical Reaction Kinetics II	O'Hayre 3.1-3.6	Homework 7 Due Homework 8 Assigned
F 4/3	Lecture 31- Chemical Reactions in Series and Parallel	O'Hayre 3.1-3.6	
M 4/6	**PHASE TRANFORMATION KINETICS** Lecture 32- Phase Transformation Kinetics Overview	O'Hayre 6.1-6.7 Barsoum 9.1-9.2	
W 4/8	Lecture 33- Phase Transformation Kinetics in Detail: Homogeneous vs. Heterogeneous Nucleation	P&E 4.0-4.1.3 P&E 5.0-5.2 O'Hayre 6.1-6.7	Homework 8 Due Homework 9 Assigned
F 4/10	Lecture 34- Phase Transformation Kinetics in Detail: Growth Rate and the JMAK Equation	P&E 5.4 O'Hayre 6.7	
M 4/13	**MICROSTRUCTRAL EVOLUTION KINETICS** Lecture 35- Thermodynamic Forces Driving Sintering/Sintering Overview	P&E 3.0-3.3.4 Barsoum 10.1-10.6 O'Hayre 7.1, 7.5	

W 4/15	Lecture 36- Densification Kinetics	Barsoum 10.1-10.6 O'Hayre 7.5	Homework 9 Due
F 4/17	Lecture 37- Coarsening and Creep Kinetics	Barsoum 10.1-10.6, 12.1-12.2 P&E 3.3.5, 3.5 O'Hayre 7.3-7.4	
M 4/20	**MECHANICAL RESPONSE KINETICS** Lecture 38- Diffusion-Induced Anelasticity		
W 4/22	**COURSE REVIEW** Lecture 39- Final Q&A, MSE 855 Jeopardy! Course Improvement, Discussion, SIRS Forms		
F 4/24	**No Class-COE Design Day**		
W 4/29	**Final Exam, 2245 Engineering Building, 5:45-7:45pm**		
Tu 5/5	*Grades Due to Registrar by 4pm*		
W 5/6	*Grades available to students on STUINFO*		