MET 422 TRANSPORT PHENOMENA

(4-0) 4 credits. Prerequisite: MATH 321 and concurrent enrollment in MET 320. The principles of momentum, heat and mass transfer and their application to metallurgical engineering. Topics covered include thermal conductivity, mass diffusion, mechanisms of transport, Fourier's and Fick's Laws, shell balance, boundary conditions, equations of change, unsteady-state transport, mass and heat distributions in turbulent flow, and interphase transport.

TEXTS

G. H. Geiger and D. R. Poirier, Transport Phenomena in Metallurgy, Springer

INSTRUCTOR

Dr. S. M. Howard MI 114 Ph. 394 -1282
Stanley.howard@sdsmt.edu Open Phone Policy/Closed Office Policy during Covid-19 risk period

REQUIRED/ELECTIVE

MET 422 is required for all B.S. Metallurgical Engineering.

COURSE OBJECTIVE

Students who satisfactorily complete this course will be able to determine velocity profiles in laminar flow systems, drag forces in turbulent flow systems, unsteady-state temperature profiles in isotropic simple solids, heat fluxes through boundary layers, net heat fluxes among gray surfaces from radiation, mass transfer rates across interphase boundaries.

COURSE OUTCOMES

- Students are expected to write Newton's Law, Fourier's Law, and Fick's Law and describe the analogies among them.
- Students will perform shell balances for momentum, heat, and mass transfer and obtain the differential equation describing the velocity, temperature, and concentration gradient.
- Students are expected to understand the difference between Newtonian and non-Newtonian flows.
- Students will be able to reduce the Equations of Continuity and Change for rectangular, cylindrical and spherical coordinates to the terms applicable for a specified condition.
- Students will be able to derive from linear, steady-state flow distributions in laminar flow volumetric and average flow equations.
- Students will be able solve ladle draining and incompressible pumping problems involving all five terms in the Overall Energy Balance.
- Students provided a set of independent variables upon which a dependent variable depends will reduce the set to a dimensionless set using Buckingham Pi Theory.
- Students will be able to design packed and fluidized beds for given system for uniform particles given their density, shape, and size and the fluid's rheolgical properties.
- Students must determine the modes of heat transfer (conduction, convection, and radiation) and describe the governing equations for each mode.
- Students are expected to calculate the heat transfer rate for convective heat transfer given heat transfer correlation and its pertinent parameters.
- Students will determine heat loss from radiative systems using Kirchoff Loop electric analog solution method.
- Students will solve 1D USS and 2D SS heat transfer and mass transfer problems using spreadsheets.
- Students will determine the concentration dependency of diffusivity.
- Students will be able to derive differential equations describing diffusion through a stagnant gas film, a moving gas stream, and a falling liquid film.
- Students will describe the mathematical similarities between turbulent convective heat transfer and turbulent diffusion including the correspondence between dimensionless groups.

CLASS SCHEDULE

1:00 – 1:50 pm MTWRF Online via D2L

TOPICS

- Introduction to analogies between Newton's, Fourier's, and Fick's Laws (1)
- Theoretical and semi-empirical equations for viscosity of gases, liquids, and molten slags (3)
- Newtonian and non-Newtonian fluids (1)

- Laminar flow and momentum balances: flow of a falling film; flow through a circular tube (3)
- Equations of continuity: rectangular volume (2)
- Substantial time derivative; total and partial time derivatives (2)
- General equations of momentum transfer: Navier-Stokes, Euler equations (2)
- Applications of the general equation of motion: flow through a long vertical cylindrical duct (1)
- Creeping flow around a sphere; flow near the leading edge of a flat plate (1)
- Dimensional analysis: Re, Fr numbers (1)
- Turbulent flow: time-smoothed quantities Interphase transport: friction factor (2)
- Flow through packed and fluidized beds (4)
- Theoretical and semi-empirical equations for thermal conductivity of fluid and solids (1)
- Heat conduction flat plates, cylinders through composite walls with generation (4)
- Heat transfer with forced and natural convection (4)
- Transient systems (2)
- Solidification heat transfer (2)
- Radiation Heat Transfer (5)
- Dimensional analysis: Nu, Gr numbers (1)
- Molar and mass flux Theoretical and semi-empirical equations for diffusivity (3)
- Diffusion in solids of gas through thin film, concentration dependent diffusivity transient diffusion (3)
- Mass transfer in fluid systems diffusion through a stagnant gas film, diffusion in a moving gas stream, diffusion into a falling liquid film, forced convection (2)
- Dimensional analysis: Sh, Sc numbers (1)
- Reviews (4)
- Hour Exams (4)

(59)

CONTRIBUTION OF COURSE TO MEETING THE PROFESSIONAL COMPONENT

- This course prepares students in the basics of transport Phenomena and, therefore, provides students with the necessary basis to design, operate and optimize metallurgical processes.
- Ethical and professional conducts are emphasized throughout the course as is societal awareness in engineering.

LABORATORY- None

ASSESSMENT AND EVALUATION

Zoom® participation and oral responses
Peer assessment
Online evaluations
Homework
Three Hour Exams
Final Exam – required by all students

EXPECTATIONS

Metallurgical Thermodynamics
College Calculus, Chemistry, Physics, Introductory Excel Spreadsheet use

COMPUTER USAGE

Excel including VBA Macros, MATLAB or similar

MET 422 SYLLABUS

OUTLINE

Approximate Class Week	Topics	Reading Assign. Pages
	Momentum Transport: Fluids	
1	Introduction to momentum, energy, and mass transfer - analogies between Newton's, Fourier's, and Fick's Laws	1-7, 185-91, 417-34
1	Theoretical and semi-empirical equations for viscosity	7-28
	Newtonian and non-Newtonian fluids	29-37
2	Laminar flow and momentum balances: flow of a falling film flow through a circular tube	39-50
3	Equations of continuity: rectangular volume, General equations of momentum transfer: Navier-Stokes, Euler equations	50-62
3	Applications of the general equation of motion: flow through a long vertical cylindrical duct, creeping flow around a sphere flow near the leading edge of a flat plate	62-74
4	Dimensional analysis: Re, Fr numbers	
	Turbulent flow: time-smoothed quantities Interphase transport: friction factor	75-90
5	Flow through packed and fluidized beds	90-112
5	Test I	
6	Overall Energy Balance	113-24
6	Flow from ladles and networks	131-44
	Heat Transport	
7	Theoretical and semi-empirical equations for thermal conductivity of fluid and solids	191-218
7	Heat conduction	281-7
8	Heat transfer with forced and natural convection	219-33
9	General Energy Equation	236-46
9	Dimensional analysis: Nu, Gr numbers: heat transfer coefficient	247-79
10	Transient Systems flat plates, cylinders through composite walls with generation Product Solution	290-327
11	Radiation Heat Transfer	369-95
12	Test II	
	Mass Transport	
12	Molar and mass flux Theoretical and semi-empirical equations for diffusivity of gases, liquids and ionic species	435-61
12	Diffusion in solids diffusion of gas through thin film, concentration dependent diffusivity transient diffusion	463-507
13	Dimensional analysis: Sh, Sc numbers	519-23
13	Mass transfer in fluid systems diffusion through a stagnant gas film diffusion in a moving gas stream diffusion into a falling liquid film forced convection	509-19
14	General Equation of Mass Transfer	523-6
14	Test III	
14	**Final Problem Projects**	

GRADING

Direct Oral Responses	10 points each	100*
Self-Evaluation	5 points each	50*
Peer Evaluations	5 points each	80*
Homework	20 points each	160*
Online Short quizzes	3 points each	60*
Three Hour exams	60 points each	180*
Final exam		100**

* These are approximate numbers based on previous sections.
** Sometimes the fourth hour exam is combined with the final.

The final grade is based directly on the total points achieved. There is no additional weighting. On rare occasions a student's grade may be raised (but never lowered) for subjective considerations such as an excellent homework file. The final grade section average is normally between 2.8 and 3.3.

POLICIES

- Students should only contact the instructor via digital means, which includes telephone calls.
- Students are free to communicate briefly in person with the instructor if they are at least 10 feet away.
- Students who are ill should not enter the MI Building. Use email and the telephone.
- All submitted work must be in digital format: no hard copy work is accepted. Handwritten work scanned into a pdf file is acceptable.
- All homework must be kept in an organized file by the student and available for inspection.
- Students who wish to be excused from required Zoom® sessions should email Dr. Howard at stanley.howard@sdsmt.edu before the absence. Excuses are allowed for sickness, emergencies, etc. Students who were unable to contact Dr. Howard before the absence occurred should discuss the absence by phone or email with Dr. Howard.
- No quizzes or exams are thrown out.
- Students will be asked to participate in class discussions and respond to questions asked by the instructor. Questions focus on previously assigned reading and lecture material.
- Conditions for the Final and the hour exams will be determined and discussed with the class a week before each exam. Exams are always open book but no computations beyond the trivial in-head is allowed. That is, all answers are algebraic.
- Dr. Howard has an open digital contact policy, but a closed in-person contact policy.
- Students are welcome to call Dr. Howard at 394-1282 or email him at stanley.howard@sdsmt.edu concerning class questions. Do not use social media to communicate with Dr. Howard or request acceptance on any social media platform. D2L may be used to contact Dr. Howard, but direct phone or email is preferred. As appropriate, Dr. Howard may invite you to contact him via mobile phone message. Specific-time appointments are discouraged unless there is a significant reason to make one. Call 394-1282 anytime from noon to 7:00 pm.

Student Integrity

As professionals in training, ethical lapses including plagiarism, cheating, or other academic dishonesty is not expected. Practices are in place to not tempt students so that they are not burdened with guilt-ridden behaviors. As your professor, I expect none but professional behavior and urge you to exercise internal regulation that will assure you do not come to think of yourself in a negative light. Such practice is an essential part of being a professional and ethical engineer necessary for success. Students should aware of the Community Standards in the SD Mines Student Catalog (Student Code of Conduct) http://www.sdsmt.edu/CommunityStandards/. Do what it takes to avoid being externally controlled. Professionals exercise internal control.

University Electronic Devices Policy

Please turn off your cell phone before class starts. No text messaging in class. No headphones. If you wish to use a laptop in this class for purposes of note taking, you may, but use of laptop is restricted to note taking and as such the laptop must be in the screen facing up note taking position. No other use of any other electronic/computer media is allowed during class time, unless required by the instructor during class.

ADA Statement

Students with special needs or requiring special accommodations should contact the instructor, Dr. M. West and/or the Title IX and Disability Coordinator, Ms. Amanda Lopez, at Amanda.Lopez@sdsmt.edu or 394-2533 at the earliest opportunity.

University Freedom in Learning Statement

Freedom in learning. Under Board of Regents and University policy student academic performance may be evaluated solely on an academic basis, not on opinions or conduct in matters unrelated to academic standards. Students should be free to take reasoned exception to the data or views offered in any course of study and to reserve judgement about matters of opinion, but they are responsible for learning the content of any course of study for which they are enrolled. Students who believe that an academic evaluation reflects prejudiced or capricious consideration of student opinions or conduct unrelated to academic standards should contact the Provost and Vice President for Academic Affairs to initiate a review of the evaluation.

Archiving Assignments and Examinations

Some students may be asked to submit copies of their assignments and examinations for the departmental archival system for ABET evaluations. All submitted information is confidential.

COVID-19 Statement

Mitigating the spread of COVID-19 is everyone's responsibility. To ensure your health and safety and that of the entire campus community, please monitor your health daily and abide by the following protocols:

- If you are exposed to COVID-19, develop COVID-19 symptoms, or anticipate being absent for more than two weeks due to COVID-19, communicate your circumstances immediately via deanofstudents@sdsmt.edu. The Dean of Students office will communicate with your instructor(s) and provide appropriate University communication to impacted parties while also preserving privacy.
- If you miss class due to medical reason, please inform your instructor(s) in a timely fashion.
- If you have been told to isolate or quarantine, you cannot attend classes in person. You should ask your instructor(s) about options for remote participation. Your instructor(s) will work with you to determine whether remote participation, an incomplete grade, or withdrawal is most appropriate.

Thank you for following these important measures to keep our community healthy and safe.

COVID-19 Attendance Policy

Out of an abundance of caution, you should contact the Dean of Students office at deanofstudents@sdmst.edu and not come to class if you experience any symptoms associated with COVID-19 (fever or chills, cough, shortness of breath or difficulty breathing, fatigue, muscle or body aches, headache, new loss of taste or smell, sore throat, congestion or runny nose, nausea or vomiting, diarrhea). The Dean of Students will contact your instructor(s). Any make-up of course requirements missed shall be worked out between you and your instructor(s). Your responsibility is to follow up with your instructor(s) quickly. Instructor(s) will respond with the aim of being flexible while retaining the integrity of your academic experience. To facilitate this process, you should do any or all of the following if you are able:

- Join scheduled synchronous remote class sessions;
- Participate in remote class activities, whether synchronous or asynchronous;
- Keep up with classwork;
- Submit assignments digitally;
- Work with your instructor(s) to try to reschedule exams, labs, and other critical academic activities.

Even if your absence has not been validated by the Dean of Students, instructors are required to allow for such make-up in a timely manner. You, on the other hand, are required to remain in timely contact with your instructor(s) to the greatest degree possible. Failure to communicate quickly and follow up my result in your inability to complete your semester.

COVID-19 Face Covering Policy

Under the COVID-19 Face Covering Protocol approved by the South Dakota Board of Regents, SD Mines begins the fall term at Level 3, which requires face coverings in all public indoor spaces on campus. If you come to class not wearing an appropriate face covering, you will be asked to put one on. If supplies exist, a disposable mask will be provided if you do not have one. If no mask is available, you will be advised about virtual education options under the Informal Correction process in the COVID-19 Face Covering Protocol. If you decline to wear a face covering and do not leave the classroom, you will be referred to the Dean of Students for Formal Correction under the COVID-19 Face Covering Protocol, which may include noncompliance with

the Student Code of Conduct. Your instructor(s) may be required to provide virtual options for you to continue to participate in the course until the allegations against you of non-compliance are resolved. Students who repeatedly come to class without a face covering will be subject to the consequences outlined in the COVID-19 Face Covering Protocol.

Statement on Recording of Lectures by Students Lectures, presentations, and other course materials are protected intellectual property under South Dakota Board of Regents Policy. Accordingly, recording and disseminating lectures, presentations or course materials is strictly prohibited without the express permission of the faculty member. Violation of this prohibition may result in the student being subject to Student Conduct proceedings under SDBOR Policy 3:4.

PREPARED BY

S. M. Howard 8/3/2020