Dr. P. M. Armenante
New Jersey Institute of Technology
January 15, 2025

Heat and Mass Transfer
ChE 370

Syllabus

Term: 2025 Spring Semester

NJIT Course Title: ChE 370 – Heat and Mass Transfer, Section 002, CRN 1114
[4 credits, 4 contact hours (4;0;0).

Class Days and Times: Monday and Wednesday, 11:30 am- 1:35 pm

Classroom: Central King Building (CKB), Room 315, NJIT

Course Instructor:
Piero M. Armenante, Ph.D.
Distinguished Professor of Chemical Engineering
Master Teacher
New Jersey Institute of Technology
Otto H. York Department of Chemical and Materials Engineering
Newark, NJ 07102

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E-Mail Address: piero.armenante@njit.edu

Instructor's Office Hours: Monday and Wednesday, 1:35-2:35 pm. Meeting room: 374 Tiernan Hall (office), or Tiernan Hall 373 (conference room), or via Zoom (https://njit-edu.zoom.us/). Students can additionally e-mail Prof. Armenante to set up appointments outside office hours, possibly to be conducted via Zoom if needed.

Teaching Assistant (TA): TBA

TA's Office Hours: TBA

Computer Software Requirements:
- NJIT e-mail account, including UCID and password, to access:
  - Canvas (https://canvas.njit.edu/)
  - Zoom (https://njit-edu.zoom.us/)
- Web browser (Chrome, Firefox, Safari, etc. - Internet Explorer is not recommended)
- Adobe Acrobat (freeware)
- Other common software to complete assignments (e.g., Microsoft Word, Microsoft Excel, **Matlab**, etc.)

Mobile Phone App Recommended:
- Office Lens (free) and/or CamScanner Apps (free)
- Cisco WebEx Meeting App (free)

Textbooks and Course Notes:

- **Textbook**: The following book is **required**:
  Cengel, Y.A. and Ghajar, A.J., "***Heat and Mass Transfer: Fundamentals and Applications***," 6th Edition, 2020. McGraw Hill. ISBN-13: 978-1260440027.
  - ***Important Remark****: Students should buy either* ***a*** **hard copy version or a loose-leaf version** *of the textbook* ***and not the e-book*** *version. Exams are* ***open-book****, and students will not be able to access computers, phones, and tablets during exams.*
  - The textbook is available in the NJIT bookstore (120 Summit Street; njit@bkstr.com; 973-596-3200; https://www.bkstr.com/njitstore/home) or from the publisher
- **Course Notes**: Armenante, P. M., 2025, *ChE 370 – Heat and Mass Transfer: Course Notes*. The *Notes* will be made available through Canvas, as needed or appropriate.

Course Prerequisite:

- CHE 201-Material and Energy Balances or ChE 240-Chemical Process Calculations II
- CHE 260-Fluid Flow
- MATH 222-Differential Equations

Course Description (from the NJIT catalog):

The principles of heat and mass transfer in chemical engineering systems are covered. Steady and unsteady heat transfer is examined, with emphasis on the heat exchanger design. Mass transfer by steady and unsteady molecular diffusion, and turbulent convective mass transfer is studied.

Overall Course Objectives:

1. To develop the students' skills in applying differential equations and numerical techniques and describing steady and transient heat and mass transfer problems
2. To develop the students' skills in using the solution to problems in heat and mass transfer components and systems to make design decisions for chemical engineering unit processes
3. To provide the students with fundamental theoretical concepts and practical analysis skills associated with convective heat and mass transfer including external and internal flow configurations
4. To provide the students with fundamental theoretical concepts and practical analysis skills associated with radiation heat transfer
5. To develop students' skills in solving practical problems in heat, mass, and momentum transfer
6. To develop the students' skills in modeling heat and mass transfer problems in different geometries

Specific Course Objectives and Learning Outcomes:

After successfully completing this course students will be able to:

1. Define and differentiate heat transfer mechanisms and bring examples of them
2. Formulate, derive, and solve 1D steady-state heat conduction problems with appropriate boundary conditions
3. Formulate, derive, and solve 1D transient heat conduction problems with appropriate initial and boundary conditions
4. Apply finite difference discretization to 1D heat conduction problems and solve the resulting set of algebraic or ordinary differential equations using numerical techniques
5. Derive the 3D differential energy balance (thermal energy equation), interpret each term, and simplify it for formulating/solving heat conduction/convection models
6. Understand the physical origin of key dimensionless parameters as a measure of competing transport rates and use these numbers to characterize system behaviors, compute the values of transport parameters, and create criteria for scaling based on dynamic similarity
7. Use the results of analytical and numerical solutions to problems in heat and mass transfer to size and select appropriate chemical process equipment such as heat exchangers
8. Formulate, derive, and solve 1D diffusion problems with appropriate boundary conditions

9. Derive the equation of continuity for the species and reduce it to formulate/solve diffusion problems
10. Recognize analogies among heat, mass and momentum transport problems and use solutions from one domain to solve problems in another
11. Through written and oral group projects, participate in the establishment of the goals and workplan for the team and contribute to the development of a collaborative team environment
12. Prepare written reports and deliver oral presentations to different audiences (both non-technical and technically skilled) to demonstrate ability to communicate effectively concepts, objectives, data, results, and project outcomes

This course explicitly addresses Student Outcomes 1, 3, 5, 7

Class Delivery Mode and Class Attendance:

The course will be delivered face-to-face. Experience shows that students who do not regularly attend class typically perform poorly in the course. In addition, examples are worked out during the lectures. These examples are not posted online. Students are responsible for all material covered in class.

Also, as required by NJIT policies "All undergraduates are expected to attend all regularly scheduled classes." (https://catalog.njit.edu/undergraduate/academic-policies-procedures/). In other terms, attendance is required.

Irrespective of any policy consideration, students who do not regularly attend classes to learn the material covered in the lectures are more likely to fail the course. In the event that class cannot meet face-to-face, the class will meet via video conferencing (e.g., Zoom, MS-Teams, or similar software).

Course Requirements:

- Exams: Three (3) exams, i.e., Midterm Exam 1, Midterm Exam 2, and Final Exam
- Homework: Assigned by the instructor as appropriate (typically weekly)
- Quizzes: Short in-class quizzes on homework just completed (typically weekly)
- Group Projects Two oral presentations and one written report
- Project: Numerical project to be assigned in the second half of the semester

Exams:

- There will be a total of three (3) exams, including the final exam
- A calendar of exams is included in the Course Outline given below
- The two midterm exams will be one-class period long (~2 hr), unless otherwise stated. The final exam will be 2 hr and 30 minutes long
- Only the following material can be used during the exams:
  - Textbook (printed version **only**)
  - Printed version of Prof. Armenante's *Course Notes*
  - 1-page cheat sheet (both sides)
  - Conversion table sheet
  - Calculator
  - No homework, copies of homework solutions, past exams, and similar material will be allowed during the exams
  - ***During exams, students will not be able to use computers or mobile phones to communicate with anyone or access any sites***
    - For this reason, **you may want to purchase *a* hard copy version or a loose-leaf version of the textbook**
- Any change in the exam policy, if needed, will be announced by the instructor prior to the exams
- The final exam will be on all material covered throughout the course
- Make-up exams will only be given to students who cannot attend the regular exam time, *and only under documented and extraordinary circumstances*. In any case, no student will be allowed to take a make-up exam unless he/she has the prior consent of the instructor. *If a student will simply not come to an exam, the exam grade will automatically be zero*

- Because of confidentiality issues, the Office of the **Dean of Students** now handles all issues related to **medical conditions** (including justification for postponing exams)

Quizzes:
- Quizzes will be given weekly to verify whether students are able to replicate the results that they achieved in their latest homework assignments
- Quizzes will consist of short weekly in-class tests (last 10 minutes of a class period, typically on Wednesday)
- Quizzes will be based on a the **most recent homework assignment** that students have completed (e.g., one of the homework problems already assigned and collected, or portion thereof) **for which the solution has already been posted**
- Quizzes are **closed-book, closed-note**
- Calculators are allowed
- *During quizzes, students will **not be able to use computers or mobile phones** to communicate with anyone or access any sites*

Homework Assignments:
- Homework assignments will be posted on Canvas as appropriate (typically on a weekly basis)
- Homework assignments will be collected by Prof. Armenante at the **beginning of the designated class period**, typically on a Monday, unless otherwise specified
- No late homework will be accepted unless a valid reason is provided **in advance** (e.g., an upcoming business trip)
- **Each problem** in each homework assignment will be graded by the TA using a scale from 0 (worst) to 10 (best). However, given the large number of students only a simplified grading approach may be used (0, 5, 10)
    - Example: if a homework assignment contains 6 problems, the maximum number of points for that assignment will be 60/60
- *However, **the score received in a given quiz will be used as a scaling factor to assign the grade to the homework related to that specific quiz.***
- Homework solutions will be posted on Canvas
- ***Important Remark**: Previous experience has clearly shown that those students who do not work on the assigned problems (or at least seriously try to solve them) typically perform poorly on the exams.*

  Homework Format:
    - **Use** only **Engineering Format paper** or similar paper for the homework (a printable copy of the engineering Format paper is available in Canvas. Alternatively, you can buy a pad)
    - **Use** appropriate **graph paper** (linear, log, semi-log) if necessary, or Engineering Format paper
    - **Draw** a **box** around **all final numerical answers** to problems
    - **Complete** all assignments in **your own handwriting**
    - **Submit** problems in the **same order** as in the homework assignment
    - **Include complete calculations** for all results presented to demonstrate how results were obtained
    - **Include** all **units** for each term in each equation. The units must be **balanced**
    - **Use** the appropriate number of **significant figures** (often two or three) for all results (but use at least two extra significant figures in calculations)
    - Make sure that you **adhere to this format** to avoid losing points

Exam, Homework, and Quiz Re-Grades:
If you believe that an error was made in grading the homework or a quiz you contact the TA with a short justification of your claim and attach it to the original homework/quiz in question. If you believe that an error was made in grading an exam or you would like to discuss any issues related to an exam you should contact Prof. Armenante instead. The "statute of limitation" for submitting such claims is one week after the homework/quiz/exam is returned.

Projects:

- The projects will consist of **three group assignments**, two oral and one written, as well as **one semi-individual computational assignment**, as follows:
- Group assignments
  - Students will organize themselves in groups of **4-5 individuals**
  - Each group will choose a **topic of their choice** related to the material covered in the course (heat and/or mass transfer) and select **three scientific/technical papers** published in the literature and related to that topic. Each group will deliver **two oral presentations**: one directed at an audience made of peers (class, professor) and another given to a city council to discuss the potential impact of a process technology based on the same topic as the first presentation.
  - The same group will also prepare a short newspaper-type of article on the same topic used for the oral presentation and directed to a wider, non-technical audience.
- Semi-individual assignment: A numerical computer project will also be assigned. This project can be completed by **an individual student or by a team made of two students not from the same group as in the group assignments above.**

Additional details will be provided during the course.

Grading Policy:

The grading policy for this course is as follows:

- Midterm Exam 1..... 20%
- Midterm Exam 2..... 20%
- Final exam..... 30%
- Homework and Quizzes* 15%
- Projects..... 15%

  Total..... 100%

Given the ubiquity of solution manuals available online, some students may be tempted to just copy the homework solution without understanding the material, thus receiving points for assignments that they did not really complete themselves.* ***In order to prevent this, the score received in a given quiz will be used as a scaling factor to assign the grade to the homework related to that specific quiz.* *For example, if a student receives 90/100 on a given homework but 3/10 in the corresponding quiz the homework grade will be scaled down to 27/100.*

Important Remark*: **I do not grade on a curve** in this course. It is theoretically possible for everyone in the class to receive an A (or an F). Your performance will depend **only** on **how you do**, not on how everyone else in the class does.*

Course Final Grade:

A tentative guideline for the assignment of final grades is the following:

Cumulative Points	*Overall Grade*
~90 to 100%	A
~75 to ~90%	B/B+
~60 to ~75%	C/C+
~50 to ~60%	"D"
0 to ~50%	F

Please remember that this is only a guideline designed to help the students understand how they are performing in the course. I will possibly slightly change the grading scale (both ways) when assigning the final grades.

I will assign the "D" grade only **sporadically**, since this implies that students in this grade category do not know appropriately well the critical content of course, which will be essential for the rest of their academic and work career. Instead students falling in the D-grade range will likely receive either a C or an F.

The grade of "Incomplete" will be given only under the most unusual and severe circumstances beyond control of the student.

If a student wishes to withdraw from the course, he/she may do so only before the date set by the Registrar's Office. Past this date a final grade will be assigned to the student.

Laptop and Mobile Phone Use:

- Although technology opens up new learning possibilities for students, sometimes students utilize it in ways that are inappropriate. **Students cannot text, e-mail, surf the Internet, play games, use Facebook, instant messaging, etc., during class time** since this is a major distraction for the student doing it as well as for others, and prevents active class participation. Cell phones must be put on silent during class. However, students may use laptops to take notes during classes.
- ***During exams and quizzes, students will not be able to use computers and mobile phones to communicate with anyone or access any sites.*** For this reason, **students need to purchase a hard copy version or a loose-leaf version of the textbook.**

Time Commitment:

Because of its importance, students are expected to spend about eight (8) hours/week in preparation for this course. Weaker students will find it necessary to spend more time.

Students are strongly urged to adjust their study and work schedule so that they will have time to cope with the demands for this course, as well as your other courses. **Falling behind in this course is extremely risky since it will be very difficult to catch up**.

Extenuating Circumstance and Other Situations:

When a student invokes extenuating circumstances for any reason (late withdrawal from a course, request for a make-up exam, request for an Incomplete grade, request for accommodation due to illness) the student should be referred to the Dean of Students Office. The Dean of Students will make the determination of whether extenuating circumstances exist and will notify the instructor accordingly. Instructors will never request or accept medical or other documents from students; all documents should be submitted by the student to the Dean of Students Office. Except for cases determined by law, an instructor is not required to accommodate student requests even when extenuating circumstances are certified by the Dean of Students; however, all efforts will be made to ensure a student-friendly environment.

NJIT Honor Code and University Code on Academic Integrity

The NJIT honor code is being upheld on all issues related to the course. Students are expected to be familiar with the code and conduct themselves accordingly. Any violations will be brought to the immediate attention of the Dean of Students.

Academic Integrity is the cornerstone of higher education and is central to the ideals of this course and the university. Cheating is strictly prohibited and devalues the degree that students are working on. As members of the NJIT community, students have the responsibility to protect their educational investment by knowing and following the NJIT University Policy on Academic Integrity that is found at http://www5.njit.edu/policies/sites/policies/files/academic-integrity-code.pdf. The Code will be upheld on all issues related to the course. Students are expected to be familiar with the code and conduct themselves accordingly. Academic integrity is fundamental to the activities and principles of a university. All members of the academic community must be confident that each person's work has been responsibly and honorably acquired, developed, and presented. Any effort to gain an advantage

not given to all students is dishonest whether or not the effort is successful. The academic community regards breaches of the academic integrity rules as extremely serious matters. Sanctions for such a violation may include academic sanctions from the instructor, including failing the course for any violation, to disciplinary sanctions ranging from probation to expulsion. When in doubt about plagiarism, paraphrasing, quoting, collaboration, or any other form of cheating, consult the course instructor. If students have additional questions about the code of Academic Integrity, they should contact the Dean of Students Office at dos@njit.edu.

Plagiarism and Academic Integrity:
The approved "University Policy on Academic Integrity" is currently in effect for all courses. Should a student fail a course due to a violation of academic integrity, they will be assigned the grade of "XF" rather than the "F," and this designation will remain permanently on their transcript. All students are encouraged to look at the University Code of Academic Integrity and understand this document. Students are expected to uphold the integrity of this institution by reporting any violation of academic integrity to the Office of the Dean of Students. The identity of the student filing the report will be kept anonymous. NJIT will continue to educate top tier students that are academically sound and are self-disciplined to uphold expected standards of professional integrity. ***Academic dishonesty will not be tolerated.***

Availability of Accessibility Resources and Services
NJIT adheres to Section 504 of the Rehabilitation Act (ADA) of 1990. Appropriate accommodations are provided at no cost to the student. The NJIT Office of Accessibility Resources and Services works in partnership with administrators, faculty and staff to provide reasonable accommodations and support services for students with disabilities who have provided that office with medical documentation to receive services. Additional questions should be directed to the NJIT Office of Accessibility Resources and Services. For further information, students should visit: https://www.njit.edu/accessibility/accommodations-and-support-services.

Important Dates According to the NJIT Calendar (Spring 2025):

January	20	Monday	Martin Luther King, Jr. Day
January	21	Tuesday	First Day of Classes
January	25	Saturday	Saturday Classes Begin
January	27	Monday	Last Day to Add/Drop a Class
January	27	Monday	Last Day for 100% Refund, Full or Partial Withdrawal
January	28	Tuesday	W Grades Posted for Course Withdrawals
February	3	Monday	Last Day for 90% Refund, Full or Partial Withdrawal, No Refund for Partial Withdrawal after this date
February	17	Monday	Last Day for 50% Refund, Full Withdrawal
March	10	Monday	Last Day for 25% Refund, Full Withdrawal
March	16	Sunday	Spring Recess Begins - No Classes Scheduled - University Open
March	22	Saturday	Spring Recess Ends
April	3	Thursday	Wellness Day
April	**7**	**Monday**	**Last Day to Withdraw**
April	18	Friday	Good Friday - No Classes Scheduled - University Closed
April	20	Sunday	Easter Sunday - No Classes Scheduled - University Closed
May	6	Tuesday	Thursday Classes Meet
May	7	Wednesday	Friday Classes Meet
May	7	Wednesday	Last Day of Classes
May	8	Thursday	Reading Day 1
May	9	Friday	Reading Day 2
May	10	Saturday	Final Exams Begin
May	16	Friday	Final Exams End
May	18	Sunday	Final Grades Due
May	19	Monday	Master's and PhD Candidate Commencement - Bloom Wellness and Events Center
May	21	Wednesday	Undergraduate Candidate Commencement - Prudential Center

Additional important dates are available on the web at the following site:
http://www.njit.edu/registrar/calendars/.

Course Outline (Spring 2025)

Week	Topic	Dates
1	Introduction, Review of Thermodynamics and Conservation Laws, Heat Transfer Mechanisms (CG: Ch. 1)	Jan. 22, 2025
1–2	Fourier's Law of Heat Conduction, 1D Heat Conduction in Various Coordinate Systems, Boundary and Initial Conditions (CG: Ch. 2)	Jan. 27-Feb. 17, 2025
3	Generalized Heat Conduction Equation in 3 Coordinate Systems and a General Approach to Solving Heat Conduction Problems (CG: Ch. 2)	
4	Thermal Resistance, Contact Resistance, Steady Conduction in Multilayer Rectangular, Cylindrical, or Spherical geometries; Heat Transfer from Finned Surfaces (CG: Ch. 3)	
5	**Exam #1**	**Feb. 19, 2025**
5–6	Lumped Parameter Systems, Transient Heat Conduction in 1D, Semi-Infinite, and Multidimensional Systems (CG: Ch. 4)	Mar. 3-Apr. 7, 2025
7	Numerical Methods in Heat Conduction (CG: Ch. 5)	
8	Fundamentals of Convection, Velocity–Thermal Boundary Layers, Laminar–Turbulent Flows, Differential Mass, Momentum, and Energy balances (CG: Ch. 6)	
9	External and Internal Forced Convection (CG: Ch. 7, 8)	
10	**Exam #2**	**Mar. 31, 2025**
10	Natural Convection, Boiling and Condensation (CG: Ch. 9, 10)	Apr. 2-May 5, 2025
11–12	Heat Exchangers, Radiation (CG: Ch. 11–13)	
12–13	Diffusion, Fick's Law, Analogy between Heat and Mass Transfer, Convective Mass Transport, Differential Species Mass Balances (CG: Ch. 14)	
	Final Exam	**Week of May 10-18, 2025**

Important: It is conceivable that some changes in the above outline may take place, depending on the overall performance of the class and the time actually required to cover the most important subjects of the course.

Additional Resources and Reference Books

- Bird, R.B., Stewart, W.E., and Lightfoot, E.N., "*Transport Phenomena*," 2nd Edition, John Wiley & Sons, New York, 2001.
- Brodkey, R.S., and Hershey, H.C., "*Transport Phenomena—A Unified Approach*," McGraw-Hill, New York, 1988.
- Carta, G., "*Heat and Mass Transfer for Chemical Engineers – Principles and Applications*," McGraw Hill, 2021. ISBN: 978-1-264-26667-8
- Welty, J., Wicks, C.E., Rorrer, G.L., "*Fundamentals of Momentum, Heat and Mass Transfer*," 5th Edition, Wiley, 2007. ISBN-13: 978-0470128688, ISBN-10: 0470128682
- Geankoplis, C.J. "*Transport Processes and Separation Process Principles*," 4th Edition, Prentice Hall, 2003, ISBN-13: 978-0131013674 ISBN-10: 013101367X .
- McCabe, W.L., Smith, J.C., and Harriott, P., "*Unit Operations of Chemical Engineering*," 5th Edition, McGraw-Hill, 1993.
- Spiegel, M.R., Lipshutz, S., Liu, J., "*Schaum's Mathematical Handbook of Formulas and Tables*,", 3rd Edition, McGraw-Hill, 2008 (Newer editions/other co-authors are also available).

There are several editions of these texts that have been used for many decades and full text PDFs can be found on the internet