ENGG*3430 Heat and Mass Transfer

Winter 2017

UNIVERSITY of GUELPH

School of Engineering

(Revision 0: December, 2017)

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1 INSTRUCTIONAL SUPPORT

1.1 Instructors

Instructor 1: Ashutosh Singh, Ph.D.
Section: 01
Office: THRN 2342, ext. 53048
Email: asingh47@uoguelph.ca
Office hours: TBA

Instructor 2: Emily Chiang, Ph.D., P.Eng.
Section: 02
Office: RICH 3519, ext. 58217
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1.2 Lab Technician

Technician: Mike Speagle
Office: RICH 3502, ext. 56803
Email: mspeagle@uoguelph.ca

1.3 Teaching Assistants

GTA	Email	Office Hours
Peter Morreale	pmorreal@uoguelph.ca	TBA
Harjeet Brar	brarh@uoguelph.ca	TBA
Thariq Mohammed	thariq@uoguelph.ca	TBA
Jaime Anderson	jander15@uoguelph.ca	TBA
Teagon Preston	prestont@mail.uoguelph.ca	TBA
Wahbi El-Bouri	welbouri@uoguelph.ca	TBA
Aurelien Osman	aosman@uoguelph.ca	TBA

2 LEARNING RESOURCES

2.1 Course Website

Course material, news, and announcements will be regularly posted to the ENGG*3430 Courselink site. You are responsible for checking the site regularly.

2.2 Required Resources

Y. Cengel and A. Ghajar, **Heat and Mass Transfer: Fundamentals and Applications**, 5th Edition, McGraw-Hill, 2014.

2.3 Recommended Resources

1. Y. Cengel and A. Ghajar, **Heat and Mass Transfer: Fundamentals and Applications**, 4th Edition, McGraw-Hill, 2010.
2. F.P. Incropera, D.P. DeWitt, T.L. Bergman, and A.S. Lavine, **Fundamentals of Heat and Mass Transfer,** 6th Edition, John Wiley and Sons, 2007.
3. V.S. Arpaci, S.H. Kao, A. Selamet, **Introduction to Heat Transfer**, 1st Edition, Prentice Hall, 1999.
4. A. Bejan, **Heat Transfer**, 1st Edition, John Wiley and Sons, 1993.
5. A. K. Datta, Biological and Bioenvironmental Heat and Mass Transfer, CRC Press, Taylor & Francis Group, Boca Raton, FL, 2002

(**Note**: Quiz, Midterm, and Final are open book exams. Therefore, you need a copy of the course textbook in order to successfully complete these tests and exams)

2.4 Additional Resources

Lecture Information: A summary of the lecture notes will be posted on the Courselink.

Lab Information: The lab manuals and lab schedule will be posted on the Courselink. You are responsible for printing the lab manuals and having them with you during the laboratory sessions.

Home Assignments: There will be approximately 13 problem sets posted in Courselink during the term. These problem sets will not be marked, but it is recommended that you do each problem set, as practice problems are the best way to learn the course. All the solutions will be posted.

Miscellaneous Information: Other information related to Heat and Mass Transfer will be posted on the web page.

2.5 Communication & Email Policy

Please use lectures and lab help sessions as your main opportunity to ask questions about the course. Major announcements will be posted to the course website. **It is your responsibility to check the course website regularly**. As per university regulations, all students are required to check their <mail.uoguelph.ca> e-mail account regularly: e-mail is the official route of communication between the

University and its student. **You are encouraged to use [ENGG3430] in the subject line while emailing your GTAs and instructors.**

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3 ASSESSMENT

3.1 Dates and Distribution

Assignments (0%): Approximately 13 Problem Sets

Quizzes and Tutorials (7.5%): Each tutorial is divided into two parts. In the first part (approximately 30 minutes), your GTA will solve and discuss one problem. In the second part of your tutorial (approximately 20 minutes) you will be asked to solve a problem. You need to make a group of two students (including yourself) for solving the problem in the second part of the tutorial. At the end of each tutorial you must submit your solution to your GTA for marking. A total 7.5% mark is allocated for such problem solving activates. You are heavily encouraged to attend your Registered Section of tutorial regularly. Writing Quizzes other than your section is not permitted and your will receive a zero grade for this.

Labs (7.5%): The purpose of performing the Heat Transfer Lab is to verify a portion of the theoretical learning in your lectures by conducting experiments. Heat Transfer Lab is located inside the "Sustainable Energy Lab (THRN 3402)". **Two tutorial classes (Week-08 and Week-09) will be reserved for the Heat Transfer Lab**. The detail schedule will be posted on your Courselink. Five experiments are designed to cover most of the basic aspects of Heat and Mass Transfer. 'Lab Manual' will be available in Courselink. You need to make a group of two students (including yourself) for performing the lab experiments. The lab report is due one week after your last experiment. Each student must submit one complete report for all experiments. A total 7.5% mark is allocated for performing all lab components.

Midterm Exam (35%): Midterm Exam (Open book exam)

Date: Friday, 17th February, 2017
Time: 7:00 – 9:00pm
Location: TBD

Final Exam (50%): Final Exam (Open book exam)

Date: Tuesday, 18th April, 2017
Time: 7:00 – 9:00pm
Location: TBA

Note: An **Open Book** means that you are allowed to bring the course textbook but not your notes and problem set solutions (If you copy solutions to the problem sets into your textbook, you will not be allowed to use it during the various tests). You are also allowed to use a **non-programmable** calculator during the tests and exams.

3.2 Course Grading Policies

Missed Assessments: If you are unable to meet an in-course requirement due to medical, psychological, or compassionate reasons, please email the course instructor. See the undergraduate calendar for information on regulations and procedures for Academic Consideration: http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-ac.shtml

Accommodation of Religious Obligations: If you are unable to meet an in-course requirement due to religious obligations, please email the course instructor within two weeks of the start of the semester to make alternate arrangements. See the undergraduate calendar for information on regulations and procedures for Academic Accommodation of Religious Obligations: http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-accomrelig.shtml

Missed Midterm Exam: If you miss the midterm due to grounds for granting academic consideration or religious accommodation, the weight of the missed midterm will be added to the final exam. **There will be no makeup midterm tests.**

Lab Work: You must attend and complete all laboratories. If you miss a laboratory due to grounds for granting academic consideration or religious accommodation, arrangements must be made with the teaching assistant to complete a makeup lab.

Late Lab Reports: Late submissions of lab reports will not be accepted.

Passing Grades: The passing grade of this course is 50% and every student must obtain a grade of 50% or higher in the Final Exam portion of the course in order for the midterm exam, laboratory write-up, and Quizzes portion of the course to count towards the final grade.

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4 AIMS, OBJECTIVES & GRADUATE ATTRIBUTES

4.1 Calendar Description

ENGG*3430 Heat and Mass Transfer W (3-1) [0.50]: Analysis of steady and transient thermal systems involving heat transfer by conduction, convection and radiation and of mass transfer by molecular diffusion and convection. Other topics include the thermal analysis of heat exchangers and heat transfer systems involving a change of state.

Prerequisite(s): ENGG*2230, ENGG*3260, MATH*2270

4.2 Course Aims

In Thermodynamics, you have learned that any form of energy can be transferred in the form of Work and Heat by interactions of a system with its surroundings. However, Thermodynamics provides no information regarding the nature of the interaction or the time rate at which the energy transfer occurs. Thermodynamics only deals with the end states of the process during which an interaction occurs. Heat and Mass Transfer is a basic engineering science that deals with rate of transfer of thermal energy. It has a broad application area ranging from biological systems to common household appliances, residential and commercial buildings, industrial processes, electronic devices, and food processing. The main goals of this introductory level course are (a) to cover the basic principles and concepts of heat and mass transfer, (b) to present real-world engineering applications to give students a feel for engineering practice, and (c)

to develop an intuitive understanding of the subject matter by emphasizing the physics and physical arguments.

4.3 Learning Objectives

This course is to introduce the basic principles of heat and mass transfer with emphasis on their analysis and applications to practical engineering problems. On successful completion of this course, you should be able to:

1. Identify important thermal processes, and derive the basic expressions for heat conduction, convection, and radiation based on the First Law of Thermodynamics
2. Analyze heat transfer processes using electrical resistance network analogy
3. Determine steady state and transient temperature distribution in various solid geometries of practical importance
4. Understand the physical significance of dimensionless parameters in convective heat/mass transfer
5. Select and apply the appropriate correlation for different heat and mass convection processes
6. Analyze and perform the thermal design of heat exchangers using conventional methods
7. Determine radiation exchange within an enclosure based on the view factor method
8. Apply appropriate numerical techniques to solve complex heat transfer problems
9. Conduct Heat and Mass Transfer laboratory tests through collecting and analyzing data using the appropriate sensors and instruments and write clear, concise and professional laboratory reports
10. Demonstrate effective skills in teamwork during group activities; demonstrate respectful interactions with peers, lab technician, teaching assistants, and instructor, self assessment

4.4 Graduate Attributes

Graduate Attribute	Learning Objectives	Assessment
1. Knowledge Base for Engineering	1, 2, 3, 4, 5, 7	Quizzes, Labs, Exams
2. Problem Analysis	1, 2, 3, 5, 6, 7, 8	Quizzes, Exams
3. Investigation	9, 10	Labs
4. Design	-	-
5. Use of Engineering Tools	-	-
6. Communication	-	-
7. Individual and Teamwork	-	-
8. Professionalism	-	-
9. Impact of Engineering on Society and the Environ.	-	-
10. Ethics and Equity	-	-
11. Environ. Society, Business, & Proj. Management	-	-
12. Life-Long Learning	-	-

4.5 Instructor's Role and Responsibility to Students

The instructor's role is to develop and deliver course material in ways that facilitate learning for a variety of students. Selected lecture notes will be made available to students on Courselink/D2L but these are not intended to be stand-alone course notes. During lectures, the instructor will expand and explain the content of notes and provide example problems that supplement posted notes. Scheduled classes will be the principal venue to provide information and feedback for tests and project.

4.6 Students' Learning Responsibilities

Students are expected to take advantage of the learning opportunities provided during lectures and tutorials. Students, especially those having difficulty with the course content, should also make use of other resources recommended by the instructor. Students who do (or may) fall behind due to illness, work, or extra-curricular activities are advised to keep the instructor informed. This will allow the instructor to recommend extra resources in a timely manner and/or provide consideration if appropriate.

4.7 Relationships with other Courses & Labs

Previous Courses:

ENGG*2230: Steady and unsteady state; 1st law and Bernoulli equation; fluid flow rate and friction; laminar and turbulent flows; non-dimensional parameters (e.g., Reynolds number)

ENGG*2400: Modeling of engineering systems

MATH*2270: Solving differential equations

ENGG*3260: System and control volume; work and heat and their interaction with the boundary and direction; energy efficiency and effectiveness of systems; thermodynamic losses;

Follow-on Courses:

ENGG*3370: Foundation for analysis of thermo-fluid systems

ENGG*3470: Foundations of energy balances, thermal flow, thermal properties; Mass transfer through fluid flows (convection), thermal fluid properties

ENGG*3830: Foundations of heat and mass balance and bioreactor design

ENGG*4230: Foundations for design of energy conversion processes

ENGG*4300: Foundations for design of food engineering process

ENGG*4330: Foundation for performance analysis of combustion systems

5 TEACHING AND LEARNING ACTIVITIES

5.1 Timetable

Lectures (Week 1 to Week 12) for Sections 101, 102, 103, 104, 105, 106, 107, 108 **(Dr. A. Singh)**

Monday	2:30 pm – 3:20 pm	MCLN 102
Wednesday	2:30 pm – 3:20 pm	MCLN 102
Friday	2:30 pm – 3:20 pm	MCLN 102

Lectures (Week 1 to Week 12) for Sections 201, 202, 203, 204, 205, 206, 207, 208 **(Dr. E. Chiang)**

Monday	1:30 pm – 2:20 pm	RICH 2520
Wednesday	1:30 pm – 2:20 pm	RICH 2520
Friday	1:30 pm – 2:20 pm	RICH 2520

Tutorials/Quizzes (Week 1 to Week 07 and Week 10 to Week 12)

Tuesday	Sec. 101 & 201	03:30PM - 04:20PM	MCKN 234
Monday	Sec. 102 & 202	10:30AM - 11:20AM	MINS 017
Tuesday	Sec. 103 & 203	08:30AM - 09:20AM	MCKN 234
Wednesday	Sec. 104 & 204	12:30PM - 01:20PM	MCKN 235
Monday	Sec. 105 & 205	03:30PM - 04:20PM	MCKN 234
Thursday	Sec. 106 & 206	11:30AM - 12:20PM	MCKN 234
Thursday	Sec. 107 & 207	10:30AM - 11:20AM	MCKN 238
Monday	Sec. 108 & 208	11:30AM - 12:20PM	MCKN 238

Laboratory Experiments (Week 08 and Week 09)

Tuesday	Sec. 101 & 201	03:30PM - 04:20PM	THRN 3402
Monday	Sec. 102 & 202	10:30AM - 11:20AM	THRN 3402
Tuesday	Sec. 103 & 203	08:30AM - 09:20AM	THRN 3402
Wednesday	Sec. 104 & 204	12:30PM - 01:20PM	THRN 3402
Monday	Sec. 105 & 205	03:30PM - 04:20PM	THRN 3402
Thursday	Sec. 106 & 206	11:30AM - 12:20PM	THRN 3402
Thursday	Sec. 107 & 207	10:30AM - 11:20AM	THRN 3402
Monday	Sec. 108 & 208	11:30AM - 12:20PM	THRN 3402

5.2 Lecture Schedule

The following table contains the tentative schedule of lecture topics.

Lectures	Lecture Topics	References*	Learning Objectives
1	Basic heat transfer	Chapter 1	1
2-3	Heat conduction equation	Chapter 2	1, 2, 3
4-10	Steady heat conduction	Chapter 3	1, 2, 3, 9
11-13	Transient conduction	Chapter 4	1, 2, 3
14-15	Numerical methods in heat conduction	Chapter 5	3, 8
16	Fundamentals of heat convection	Chapter 6	1, 2, 4
17-19	External forced convection	Chapter 7	1, 2, 4, 5, 9
20-22	Internal forced convection	Chapter 8	1, 2, 4, 5
23-25	Natural convection	Chapter 9	1, 2, 4, 5,9
26-29	Heat exchangers	Chapter 11	6, 9
30-31	Fundamentals of thermal radiation	Chapter 12	1
32-34	Radiation heat transfer	Chapter 13	1, 2, 7, 9
35-36	Mass Transfer	Chapter 14	1,2

* Y. Cengel and A. Ghajar, **Heat and Mass Transfer: Fundamentals and Applications**, 5th Edition, McGraw-Hill, 2014.

5.3 Tutorial Schedule

Week	Activity	References
1	Problem solving (30 min. approx.) and Quiz (20 min. approx.)	Review of Thermodynamics
2	Problem solving (30 min. approx.) and Quiz (20 min. approx.)	Lecture (week 1)
3	Problem solving (30 min. approx.) and Quiz (20 min. approx.)	Lecture (week 2)
4	Problem solving (30 min. approx.) and Quiz (20 min. approx.)	Lecture (week 3)
5	Problem solving (30 min. approx.) and Quiz (20 min. approx.)	Lecture (week 4)
6	Problem solving (30 min. approx.) and Quiz (20 min. approx.)	Lecture (week 5)
7	Problem solving (30 min. approx.) and Quiz (20 min. approx.)	Lecture (week 6)
8	Lab experiments (in THRN 3402)	Lab manuals (Courselink)
9	Lab experiments (in THRN 3402)	Lab manuals (Courselink)
10	Problem solving (30 min. approx.) and Quiz (20 min. approx.)	Lecture (week 7, 8)
11	Problem solving (30 min. approx.) and Quiz (20 min. approx.)	Lecture (week 8, 9)
12	Problem solving and lab report submission	Lecture (weeks 10 - 11)

5.4 Lab Schedule

Week	Topic	Due
10, 11	**Lab 1**: Investigation of modes of heat transfer **Description**: Conduction through solid walls; Natural convection from vertical wall; Radiation from different colored surfaces; Thermal contact resistances; Energy balance; Isoflux and convection boundary conditions **Engineering Tool Introduced**: Thermocouple, infrared thermometer, thermistor, heat flux sensor, panel meter, heat source, thermal cavity	One week after your last lab session
10, 11	**Lab 2**: Radiation heat transfer and inverse square law **Description**: Radiation from point source; Radiation intensity as a function of distance; Temperature of a point source **Engineering Tool Introduced**: Radiation sensor, mili-volt meter, pyrometer, point thermal source	One week after your last lab session
10, 11	**Lab 3**: Convection due to density gradient **Description**: Natural circulation due to density gradient; Thermal stratification **Engineering Tool Introduced**: Salinity meter, long-probe thermometer	One week after your last lab session
10, 11	**Lab 4**: Convection due to salinity gradient **Description**: Natural circulation due to salinity gradient; Thermal stratification **Engineering Tool Introduced**: Salinity meter, long-probe thermometer	One week after your last lab session
10, 11	**Lab 5**: Performance test of heat exchangers **Description**: 1-sheel and 1-tube liquid-liquid heat exchanger; 1-shell and multiple-tube liquid-liquid heat exchanger; cross flow liquid-gas heat exchanger **Engineering Tool Introduced**: Different type heat exchangers, constant temperature bath	One week after your last lab session

5.5 Other Important Dates

Monday, 9th January, 2017: Winter 2017 Semester Starts

Monday, 9th January, 2017: First lecture of Heat and Mass Transfer

Monday, 20th February, 2017 to Friday, 24th February, 2017: Winter Break

Friday, 10th March, 2017: 40th class day – Last day to drop one semester courses

Friday, 7th April, 2017: Classes conclude

Monday, 10th April, 2017: Examinations commence

6 LAB SAFETY

Safety is critically important to the School and is the responsibility of all members of the School: faculty, staff and students. As a student in a lab course you are responsible for taking all reasonable safety precautions and following the lab safety rules specific to the lab you are working in. In addition, you are responsible for reporting all safety issues to the laboratory supervisor, GTA or faculty responsible. If the laboratory rules are not followed, consequences will include removing access to the lab. If these results in lab work not being completed, the student will receive a grade of 0.

All students must require a basic safety related training. Complete the online **WHMIS** (Workplace Hazardous Materials Information System) training before the first lab experiment session. Visit Environmental Heath and Safety website (http://www.uoguelph.ca/ehs/courses/login.cfm) for registration and additional information. Your GTA and Lab Technician may ask you to show them a copy of the WHMIS completion certificate anytime during your lab session.

6.1 Specific for ENGG*3430:

- At the beginning of your first lab experiment session (Week 8) the Sustainable Energy Lab Technician and GTA will deliver a short lecture on the lab safety in general and specific to ENGG*3430. **You must attend this safety lecture session and sign the signature sheet available in the lab.**
- Your Lab Technical and GTA will train you before the first use of any critical instrument.
- You must read the experiment manuals carefully. You will find additional safety requirement related to specific excrements in the manuals. Follow them accordingly.
- You must read and follow safety rules posted on the door of the Sustainable Energy Lab (THRN3402).
- Always wear safety glasses during lab time.

7 ACADEMIC MISCONDUCT

The University of Guelph is committed to upholding the highest standards of academic integrity and it is the responsibility of all members of the University community faculty, staff, and students to be aware of what constitutes academic misconduct and to do as much as possible to prevent academic offences from occurring. University of Guelph students have the responsibility of abiding by the University's policy on academic misconduct regardless of their location of study; faculty, staff and students have the responsibility of supporting an environment that discourages misconduct. Students need to remain aware that instructors have access to and the right to use electronic and other means of detection.

Please note: Whether or not a student intended to commit academic misconduct is not relevant for a finding of guilt. Hurried or careless submission of assignments does not excuse students from responsibility for verifying the academic integrity of their work before submitting it. Students who are in

any doubt as to whether an action on their part could be construed as an academic offence should consult with a faculty member.

7.1 Resources

The Academic Misconduct Policy is detailed in the Undergraduate Calendar:
http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-amisconduct.shtml

A tutorial on Academic Misconduct produced by the Learning Commons can be found at:
http://www.academicintegrity.uoguelph.ca/

Please also review the section on Academic Misconduct in your Engineering Program Guide.

The School of Engineering has adopted a Code of Ethics that can be found at:
http://www.uoguelph.ca/engineering/undergrad-counselling-ethics

8 ACCESSIBILITY

The University of Guelph is committed to creating a barrier-free environment. Providing services for students is a shared responsibility among students, faculty and administrators. This relationship is based on respect of individual rights, the dignity of the individual and the University community's shared commitment to an open and supportive learning environment. Students requiring service or accommodation, whether due to an identified, ongoing disability for a short-term disability should contact the Centre for Students with Disabilities as soon as possible.

For more information, contact CSD at 519-824-4120 ext. 56208 or email csd@uoguelph.ca or see the website: http://www.csd.uoguelph.ca/csd/

9 RECORDING OF MATERIALS

Presentations which are made in relation to course work—including lectures—cannot be recorded or copied without the permission of the presenter, whether the instructor, classmate or guest lecturer. Material recorded with permission is restricted to use for that course unless further permission is granted.

10 RESOURCES

The Academic Calendars are the source of information about the University of Guelph's procedures, policies and regulations which apply to undergraduate, graduate and diploma programs: http://www.uoguelph.ca/registrar/calendars/index.cfm?index