ME EN 7670 Advanced Radiation Heat Transfer
Department of Mechanical Engineering
University of Utah
Fall 2012

Instructor:	Prof. Mathieu Francoeur Office: 2126 MEB Phone: 801-581-5721 Email: mfrancoeur@mech.utah.edu
Office Hours:	By appointment
Class Schedule:	M,W,F 10:45 am – 11:35 pm WEB 1460
Required Textbook:	M.F. Modest, *Radiative Heat Transfer*, 2nd edition, Academic Press, 2003 (ISBN 0-12-503163-7).
Other Textbook:	J.R. Howell, R. Siegel, and M.P. Mengüç, *Thermal Radiation Heat Transfer*, 5th edition, CRC Press, 2011 (ISBN 978-1-4398-0533-6).
Course Summary:	Provide the student with a fundamental understanding of radiation heat transfer. At the end of the class, the student should be comfortable with the blackbody concept and surface radiative properties, radiative heat exchange between surfaces separated by transparent media, radiative heat transfer in absorbing, emitting and scattering media, the radiative transfer equation and the associated solution methods, especially the discrete ordinates method. After this class, it is expected that the student will be able to read and understand the radiation heat transfer literature.
Prerequisites:	ME EN 3650: Heat Transfer Graduate Status

Grading:

Mid-term exam 1 (take-home)	25%
Mid-term exam 2 (take-home)	25%
Final quiz (in class)	10%
Homework	40%
	100%

Grading Scale:

93 – 100%:	A
90 – 92%:	A-
87 – 89%:	B+
83 – 86%:	B
80 – 82%:	B-
77 – 79%:	C+
73 – 76%:	C
70 – 72%:	C-

67 – 69%:	D+
63 – 66%:	D
60 – 62%:	D-
below 60%:	E

Final grading scale may be lowered by the instructor based on the overall class performance, but will not be raised.

Exams: Two mid-term exams (take-home) and a final quiz (in class) are scheduled. The final quiz will be comprehensive. In the event of a missed exam/quiz, students will be required to provide a valid explanation for the conflict and will be required to complete a make-up exam/quiz. Please notify the instructor as soon as possible if you are unable to take an exam/quiz at the scheduled time.

Homework: In general, homework will be assigned on a bi-weekly basis. Homework will be collected at the beginning of the class period when due. No late homework will be accepted, unless the student has a valid reason.

Class Policies: i) All work submitted for grading should represent your individual effort. Since engineering is a group activity, students are highly encouraged to help each other to learn the course material and to discuss the homework assignments. However, all homework submitted <u>must be each student's personal work</u>. Students submitting work showing evidence of copying will receive zero credit.
ii) Submitting work copied from others will be considered academic misconduct. Plagiarism of ideas or work as well as giving or receiving unauthorized information on examinations will be considered academic misconduct. All academic misconduct will be dealt with severely and may result in a course grade of E.
iii) Laptop computers may only be used to take notes. The use of cell phones is strictly prohibited in the classroom.
iv) During the lectures, students are expected and encouraged to ask questions and participate in discussions. However, it may happen that some individuals have different points of view. While such an interactive and animated environment is usually beneficial from a learning standpoint, any disrespectful behavior toward the instructor or a classmate will not be tolerated. Any student showing such disrespectful behavior will be asked to leave the classroom.

Class Attendance: i) It is your decision whether or not to attend class.
ii) If you have a University athletic or academic activity or a business engagement, please contact the instructor before you leave to determine appropriate accommodations for the absence.
iii) If you are absent for any other reason, please contact your classmates for any pertinent material. Do not see the instructor for notes and handouts.

Class Website: i) A Canvas course website has been established. Syllabus, PowerPoint presentations, homework assignments, homework solutions, and other useful documentation will be posted at the course website.
ii) Electronic communication with all students will be made using a class email list compiled with the registrar. If your email address listed with the registrar is out of date, please update it by accessing the Campus Information System (CIS).

Course Objectives: At the end of this course, the student will:

1. Be knowledgeable of Planck's blackbody distribution (formulation, application and limitation) and Wien's law
2. Understand the concept of solid angle and be able to calculate solid angles
3. Be able to understand the similarities and differences between radiative intensity, radiative heat flux and emissive power
4. Understand surface radiative properties (emissivity, absorptivity, reflectivity) and be able to distinguish and link spectral, total, directional and hemispherical properties
5. Understand the concept of view factor in radiative transfer and be able to calculate these quantities for a variety of geometries via view factor algebra, the cross-strings method and the Monte Carlo method
6. Be able to predict radiation heat transfer between black surfaces separated by transparent media
7. Be able to predict radiation heat transfer between gray, diffuse surfaces separated by transparent media
8. Understand how radiation heat transfer between nongray surfaces can be predicted
9. Understand the phenomena of absorption, emission, in-scattering and out-scattering in participating media
10. Be able to formulate the radiative transfer equation for radiation heat transfer in participating media
11. Understand how radiative heat transfer is coupled with other heat transfer modes via the energy equation
12. Be able to solve analytically the radiative transfer equation for simple cases involving radiative equilibrium of non-scattering and scattering media (exact solutions)
13. Be able to solve analytically the radiative transfer equation in the optically thick limit and via the two-flux approximation
14. Be able to solve computationally the radiative transfer equation in a one-dimensional slab via the discrete ordinates method
15. Understand collimated irradiation and be able to integrate it in the radiative transfer equation
16. Be able to account for transient effects in the radiative transfer equation when dealing with short-pulsed collimated irradiation

Americans with Disabilities Act of 1990:

The University of Utah seeks to provide equal access to its programs, services and activities for people with disabilities. If you will need accommodations in the class, reasonable prior notice needs to be given to the Center for Disability Services, 162 Olpin Union Building, 581-5020 (V/TDD). CDS will work with you and the instructor to make arrangements for accommodations. All written information in this course can be made available in alternative format with prior notification to the Center for Disability Services.

Topics to be Covered (subject to change):

Topic 1: Fundamentals of Thermal Radiation

A. Introduction (**Section 1.1**)
B. Nature of thermal radiation (**Section 1.2**)
C. Basic laws and blackbody concept (**Sections 1.3 and 1.4**)
D. Solid angles (**Section 1.5**)
E. Radiative intensity and radiative heat flux (**Sections 1.6 and 1.7**)
F. Radiation pressure (**Section 1.8**)
G. Introduction to radiation characteristics of various media (**Sections 1.10 to 1.14**)

Topic 2: Radiative Properties of Surfaces

A. Emissivity (**Sections 3.1 and 3.2**)
B. Absorptivity (**Sections 3.1 and 3.2**)
C. Reflectivity (**Sections 3.1 and 3.2**)
D. Real surfaces (**Overview of Sections 3.4 to 3.7, and 3.9**)

Topic 3: View Factors

A. Definition (**Sections 4.1 to 4.3**)
B. View factor algebra (**Section 4.6**)
C. The crossed-strings method (**Section 4.7**)

Topic 4: Radiation Transfer between Surfaces Separated by Transparent (Non-Participating) Media

A. Radiation transfer between black surfaces (**Sections 5.1 and 5.2**)
B. Radiation transfer between gray, diffuse surfaces (**Sections 5.3 and 5.4**)
C. Radiation transfer between nongray surfaces (**Sections 7.1 and 7.2**)
D. The Monte Carlo method (**Sections 20.1 to 20.6**)

Topic 5: Radiation Transfer in Participating Media

A. Introduction (**Sections 9.1 and 9.2**)
B. Attenuation of radiation: absorption and out-scattering (**Section 9.3**)
C. Augmentation of radiation: emission and in-scattering (**Section 9.4**)
D. The radiative transfer equation (RTE) (**Sections 9.5 to 9.8**)
E. Coupling the RTE with the energy equation (**Sections 9.9 to 9.12**)
F. Overview of solution methods for the RTE (**Section 9.13**)

Topic 6: Exact Solutions of the RTE in One-Dimensional Plane-Parallel Gray Media

A. Formulation of the problem (**Sections 13.1 and 13.2**)
B. Radiative equilibrium of a non-scattering medium (**Section 13.3**)
C. Radiative equilibrium of a scattering medium (**Section 13.4**)

Topic 7: Approximate Solutions of the RTE

A. The optically thick approximation (**Section 14.2**)
B. The Schuster-Schwarzschild approximation (**Section 14.3**)
C. The discrete ordinates method (**Chapter 16**)

Topic 8: Treatment of Collimated Irradiation

A. Steady-state RTE with collimated irradiation (**Sections 18.1 to 18.3**)
B. Short-pulsed collimated irradiation and transient effects (**Section 18.4**)

ME EN 7670 – Advanced Radiation Heat Transfer
Fall 2012 Schedule (tentative):

Week	Class #	Date	Day	Topics
1	1	Aug. 20	M	Syllabus and Introduction
	2	Aug. 22	W	Topic 1
	3	Aug. 24	F	Topic 1
2	4	Aug. 27	M	Topic 1
	5	Aug. 29	W	Topic 1
	6	Aug. 31	F	Topic 1
3		Sep. 3	M	**Labor Day holiday**
	7	Sep. 5	W	Topic 2
	8	Sep. 7	F	Topic 2
4	9	Sep. 10	M	Topic 2
	10	Sep. 12	W	Topic 2
	11	Sep. 14	F	Topic 3
5	12	Sep. 17	M	Topic 3
	13	Sep. 19	W	Topic 3
	14	Sep. 21	F	Topic 3
6	15	Sep. 24	M	Topic 4
	16	Sep. 26	W	Topic 4
	17	Sep. 28	F	Topic 4
7	18	Oct. 1	M	Topic 4
	19	Oct. 3	W	Topic 4
	20	Oct. 5	F	Topic 4, **Mid-Term Exam 1 due (no later than Oct. 5, 5 pm)**
8		Oct. 8	M	**Fall Break**
		Oct. 10	W	**Fall Break**
		Oct. 12	F	**Fall Break**
9	21	Oct. 15	M	Topic 4
	22	Oct. 17	W	Topic 4
	23	Oct. 19	F	Topic 4
10	24	Oct. 22	M	Topic 4
	25	Oct. 24	W	Topic 5
	26	Oct. 26	F	Topic 5
11	27	Oct. 29	M	Topic 5
	28	Oct. 31	W	Topic 5
	29	Nov. 2	F	Topic 5
12	30	Nov. 5	M	Topic 5
	31	Nov. 7	W	Topic 6
	32	Nov. 9	F	Topic 6
13	33	Nov. 12	M	Topic 7
	34	Nov. 14	W	Topic 7
	35	Nov. 16	F	Topic 7
14	36	Nov. 19	M	Topic 7
	37	Nov. 21	W	Topic 7
		Nov. 23	F	**Thanksgiving holiday**
15	38	Nov. 26	M	Topic 7
	39	Nov. 28	W	Topic 7
	40	Nov. 30	F	Topic 8
16	41	Dec. 3	M	Topic 8
	42	Dec. 5	W	Topic 8
	43	Dec. 7	F	**Final quiz**
17				**Mid-Term Exam 2 due (no later than Dec. 14, 5 pm)**