THE UNIVERSITY OF UTAH

ME EN 7670 Advanced Radiation Heat Transfer
Department of Mechanical Engineering
University of Utah
Fall 2014

Instructor: Prof. Mathieu Francoeur
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Office Hours: By appointment

Class Schedule: M,W,F
10:45 am – 11:35 am
WEB 1450

Required Textbook: M.F. Modest, *Radiative Heat Transfer*, 3rd edition, Academic Press, 2013 (ISBN: 978-0-12-386944-9).

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, radiative properties of particulate 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 must be each student's personal work. 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). Note that CANVAS email will not be supported.

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. 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 basics of the Maxwell equations and be able to apply the electromagnetic wave theory for predicting radiative properties of surfaces
6. 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 approach and the Monte Carlo method
7. Be able to predict radiation heat transfer between black surfaces separated by transparent media
8. Be able to predict radiation heat transfer between gray, diffuse surfaces separated by transparent media
9. Understand how radiation heat transfer between nongray surfaces can be predicted
10. Understand the phenomena of absorption, emission, in-scattering and out-scattering in participating media
11. Be able to formulate the radiative transfer equation for radiation heat transfer in participating media
12. Understand how radiative heat transfer is coupled with other heat transfer modes via the energy equation
13. Be able to apply the Mie theory for calculating electromagnetic wave absorption and scattering by a single sphere
14. Be able to calculate radiative properties of particulate media using the electromagnetic wave theory
15. Be able to solve analytically the radiative transfer equation for simple cases involving radiative equilibrium of non-scattering and scattering media (exact solutions)
16. Be able to solve the radiative transfer equation in a one-dimensional slab via the discrete ordinates method

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, 1.4**)
D. Solid angles (**Section 1.5**)
E. Radiative intensity and radiative heat flux (**Sections 1.6, 1.7**)
F. Introduction to the radiative transfer equation (**Sections 1.10-1.16**)

Topic 2: Radiative Properties of Surfaces

A. Emissivity (**Sections 3.1, 3.2**)
B. Absorptivity (**Sections 3.1, 3.2**)
C. Reflectivity (**Sections 3.1, 3.2**)
D. Predictions from the electromagnetic wave theory (**Sections 2.1-2.5, 3.3**)

Topic 3: View Factors

A. Definition (**Sections 4.1-4.3**)
B. View factor algebra (**Section 4.6**)
C. The crossed-strings method (**Section 4.7**)
D. The Monte Carlo method (**Chapter 8**)

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

A. Radiation transfer between black surfaces (**Sections 5.1, 5.2**)
B. Radiation transfer between gray, diffuse surfaces (**Sections 5.3, 5.4**)
C. Radiation transfer between nongray surfaces (**Sections 7.1, 7.2**)

Topic 5: Radiation Transfer in Participating Media

A. Introduction (**Section 10.1**)
B. Attenuation of radiation: absorption and out-scattering (**Section 10.2**)
C. Augmentation of radiation: emission and in-scattering (**Section 10.3**)
D. The radiative transfer equation (RTE) (**Sections 10.4-10.10**)
E. Coupling of the RTE with the energy equation (**Section 10.11**)
F. Overview of solution methods for the RTE (**Section 10.12**)

Topic 6: Radiative Properties of Particulate Media

A. Introduction (**Section 12.1**)
B. Mie theory: Absorption and scattering by a single sphere (**Sections 12.2, 12.4-12.7**)
C. Radiative properties of a particle cloud (**Section 12.3**)
D. Approximate scattering phase function (**Section 12.9**)
E. Irregular particles and aggregates (**Section 12.10**)

Topic 7: Exact Solutions of the RTE in One-Dimensional Plane-Parallel Gray Media

A. Formulation of the problem (**Sections 14.1, 14.2**)
B. Plane layer of a non-scattering medium (**Section 14.3**)
C. Plane layer of a scattering medium (**Section 14.4**)

Topic 8: The discrete ordinates method

A. Introduction (**Section 17.1**)
B. Discretization (**Section 17.2**)
C. Discretized RTE and boundary conditions (**Section 17.3**)
D. Solution procedure (**Notes**)
E. Anisotropic scattering (**Notes**)

ME EN 7670 – Advanced Radiation Heat Transfer
Fall 2014 Schedule (tentative):

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