
Week 1

Lecture 1
Information provided:

• Instructor: M.M. Yovanovich, CPH 3375C X3588, E3-2133A, X6181 or X4586
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• Teaching Assistants:
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• Text: Engineering Thermodynamics, 2nd Edition 1977
by W.C. Reynolds and H.C. Perkins

• Students are requested to sign in

• Final Grade Components and Weights
Project 1 Part 1: 8 points Project 1 Part 2: 2 points
Project 2 Part 1: 8 points Project 2 Part 2: 2 points
Mid Term Examination: 30 points
Final Examination: 50 points

• ECE 309 web site: http://www.mhtl.uwaterloo.ca/courses/ece309/ece309.html

• Course material and information will be available at this web site.

• ECE 309 lectures are cancelled during week 9: June 28-July 2.
Dates and times for makeup lectures will be arranged later.

• Midterm Examination: Week 6, June 7-11. To be arranged later.
• Final Examination: After August 4. August 6-9. To be arranged.

• Read Chapter 14: Heat Transfer
Do Problems: 1, 6, 7, 11, 14, 18, 25, 28, 29
Solutions will be posted in DC Library
No Tutorial this week

• Modes of heat transfer: **Conduction, Convection and Radiation**

• Definitions of heat transfer by conduction, convection and radiation
Show and tell: circulate examples of air cooled heat sinks

Lecture 2

• Room E1-2536 for Wednesday Lectures throughout term.
• Introduction to and tour of ECE 309 web site.
• Maple V R 5 will be used to illustrate the concepts; solve problems; provide solutions to asigned projects; provide solutions to examination problems, etc.

• Conduction: **Fourier's Law of Conduction**: $\boxed{\dot{Q} = -kA\nabla T}$ or $\boxed{\vec{q} = -k\nabla T}$; thermal conductivity k; units of $\dot{Q}$, q, T, ∇T

• Appendix C contains values of thermal conductivity for solids, liquids and gases; range of values from diamond at $2000-2300$ $W/m{\cdot}K$ to air at 0.0265 $W/m{\cdot}K$. The range can be extended to much lower and much higher values by means of engineered systems such as *super insulation* and heat pipes.

• Definitions of thermal resistance R and shape factor S; their units and relationships.

$$R = \frac{T_1 - T_2}{\dot{Q}} \quad \text{and} \quad S = \frac{1}{kR}$$

• Thermal circuit with temperature nodes: T_1, T_2, thermal resistor: R and throughput: $\dot{Q}$.

Steady conduction through a plane wall of thickness: L, conduction area: A, constant thermal conductivity: k, which has boundary temperatures: T_1, T_2 where $T_1 > T_2$ is given by Fourier's Law of Conduction:

$$\dot{Q} = kA\frac{T_1 - T_2}{L}$$

The thermal resistance and shape factors for this system are:

$$R = \frac{L}{kA} \quad \text{and} \quad S = \frac{A}{L}$$

The thermal resistance is analogous to the electrical resistance of a constant cross-section wire of length: L, area: A, and electrical conductivity σ:

$$R_{\mathrm{e}} = \frac{L}{\sigma A} = \rho_{\mathrm{e}} \frac{L}{A}$$

where ρ_e is the electrical resistivity of the wire.

Lecture 3

• **Newton's Law of Cooling**:
$\boxed{\dot{Q}_{\mathrm{conv}} = hA(T_{\mathrm{w}} - T_{\infty})}$.
• Heat transfer coefficient h: its units are $[W/m^2 K]$. It is complex (depends on several parameters: geometric, thermophysical properties, type of flow, boundary condition, etc). $h = h(\rho, k_f, c_p, \mu, T_s, T_{\infty}, \text{velocity}, \text{geometry}, \text{flow direction}, etc)$.
• **film resistance**:
$\boxed{R_{\mathrm{film}} = 1/(hA)}$.
• Thermal boundary layer resistor. Ranges of typical values of h are given at ECE 309 web site for natural and forced convection of gases and liquids, etc.

• **Stefan-Boltzmann Law of Radiation**:

$\boxed{\dot{Q}_{12} = \dfrac{E_{b1} - E_{b2}}{R_{\mathrm{rad}}}}$ where $E_{b1} = \sigma T_1^4, E_{b2} = \sigma T_2^4$ are blackbody radiative nodes, and T_1, T_2 are absolute temperatures of the isothermal gray surfaces.
• **Stefan-Boltzmann constant**
$\sigma = 5.67 \times 10^{-8}\ W/m^2 \cdot K^4$
• Radiative resistances:
• $R_{\mathrm{rad}} = R_{s1} + R_{12} + R_{s2}$ where R_{s1}, R_{s2} are gray-surface radiative resistances and R_{12} is the spatial radiative resistance.
• Units of these radiative resistances are m^{-2}.

• Gray surface resistances:

$$R_{s1} = \frac{1 - \epsilon_1}{A_1\, \epsilon_1} \qquad \text{and} \qquad R_{s2} = \frac{1 - \epsilon_2}{A_2\, \epsilon_2}$$

with $0 < \epsilon_1 < 1$ and $0 < \epsilon_2 < 1$. When $\epsilon_1 = 1$ and $\epsilon_2 = 1$, the gray surface relation goes to the blackbody relation and the two surface resistances vanish, i.e. $R_{s1} = 0, R_{s2} = 0$. See ECE 309 web site for additional information, and Appendix $C \cdot 7$ for nominal values for a range of materials and conditions.

• Spatial radiative resistance: $R_{12} = 1/(A_1 F_{12}) = 1/(A_2 F_{21})$ where A_1, A_2 are the surface areas of the radiating gray surfaces; F_{12}, F_{21} are dimensionless radiative view factors: $0 \le F_{12} \le 1, 0 \le F_{21} \le 1$.
