University of Macau
Department of Electromechanical Engineering
MECH316 – Heat Transfer
Syllabus
2nd Semester 2011/2012
Part A – Course Outline

Compulsory course in Electromechanical Engineering

Course description:
Fundamental of heat transfer, including one and two dimensional steady state heat conduction, transient heat conduction, numerical solutions for heat conduction problem, basic convective heat transfer and thermal radiation. Applications of heat transfer in engineering systems.

Prerequisite:
MECH315 - Thermodynamics

Textbook:
- Cengel Yunus, Ghajar Afshin, ***Heat and Mass Transfer: Fundamentals and Applications***, 4th Edition, McGraw-Hill, 2010.

References:
- Incropera, F. P., DeWitt, D. P., Introduction to Heat Transfer, 5th Edition, John Wiley & Sons, 2007.
- Holman, J. P., Heat Transfer, 10th Edition, McGraw-Hill, 2009.

Course objectives:
1. Introduce the physical concepts and laws of energy balance, modes of heat transfer, and related material properties, one-dimensional and multi-dimensional, steady and transient state conduction heat transfer, and relevant initial and boundary conditions. [a, e]
2. Learn the analytical and numerical solution techniques in solving specific heat conduction problems with heat generation and fins. [a, e, l]
3. Use analytical, numerical, and graphical solution techniques in solving specific transient heat conduction problems, including lumped, one-dimensional and multi-dimensional systems. [a, e, l]
4. Introduce the physical concepts, laws and governing equations of convection heat transfer. Learn to analyze the heat convection problems for laminar and turbulent flows in internal and external configurations. Understand the use of different empirical correlations for obtaining convection heat transfer coefficients. [a, e]

Topics covered:
1. **Introduction to Heat Transfer –** Thermodynamics vs. Heat Transfer; Applications of Heat Transfer; Heat and Other Forms of Energy; Specific Heat; Energy Transfer; The First Law of Thermodynamics; Control Volume; Surface Energy Balance; Heat Transfer Mechanisms: Conduction, Convection, and Radiation; Fourier's Law of Heat Conduction; Thermal Conductivity; Classification of Convection; Newton's Law of Cooling; Convection Heat Transfer Coefficient; Stefan-Boltzmann Law; Absorptivity in Radiation; Radiation between Surfaces; Problem Solving Technique.
2. **Heat Conduction Equation** – Heat Transfer & Temperature; Transient vs. Steady; Multidimensional Heat Transfer; Heat Conduction Vector; One-Dimensional Heat Conduction Equations in a Large Plane Wall, in a Long Cylinder, and in a Sphere; Multi-Dimensional General Conduction Equations; Boundary Conditions in Heat Transfer; Solving Steady 1D Conduction Problems; Heat Generation in a Solid; Variable Thermal Conductivity.
3. **Steady Heat Conduction –** Thermal Resistance Concept; Thermal Resistance Network in Plane Walls, in Cylinders, and in Spheres; Thermal Contact Resistance; Critical Radius of Insulation; Finned Surfaces; Boundary Conditions at Fin Base and Fin Tip; Fin Efficiency; Fin Effectiveness; Overall Effectiveness of Fins; Proper Length of a Fin; Heat Transfer in Common Configurations; Conduction Shape Factor.

4. **Transient Heat Conduction** – Lumped System Analysis; Criteria for Lumped System Analysis; Biot Number; Spatial Effects; One-Term Approximation to Solution & Graphical Solution of the Transient 1D Heat Conduction Problem; Transient in Semi-Infinite Solids; Analytical Solution of the Transient 1D Heat Conduction Problem in a Semi-Infinite Medium; Product Solution of the Transient Conduction & Heat Transfer in Multi-Dimensional Systems.
5. **Numerical Methods in Heat Conduction –** 1D & 2D Finite Difference Method; Energy Balance Method; Mirror Image Concept; Implicit & Explicit Methods in Transient Heat Conduction; Stability Criterion for Explicit Method.
6. **Fundamentals of Heat Convection –** Nusselt Number; Classification of Fluid Flows; No-Slip Condition; Velocity Boundary Layer; Thermal Boundary Layer; Prandtl Number; Laminar & Turbulent Flows; Reynolds Number.
7. **External Forced Convection** – Practical External Flows; Drag Coefficient & Friction Coefficient; Parallel Flow Over Flat Plates; Critical Reynolds Number; Average Values and Local Values of Friction Coefficient and Nusselt Number; Flow Across Cylinders & Spheres; Effect on Surface Roughness; Flow Across Tube Banks; Tube Arrangement; Heat Transfer by Tube Bank; Pressure Drop Across Tube Bank.
8. **Internal Forced Convection** – Mean Velocity; Mean Temperature; Bulk Mean Fluid Temperature; Entrance Region; Fully Developed Region; Surface Thermal Conductions: Constant Surface Heat Flux, Constant Surface Temperature; Log Mean Temperature Difference (LMTD), Number of Transfer Units (NTU); Laminar and Turbulent Flows in Tubes; Some Empirical Correlations; Heat Transfer Enhancement in Tubes.

Class schedule and credits:

Timetabled work in hours per week			No of teaching weeks	Total hours	Total credits	No / Duration of exam papers
Lecture	Tutorial	Practice				
2	1	1	14	56	3	1 / 3 hours

Topic Outline:

Week No.	No. of hours	Topics
1	4	**Introduction to Heat Transfer** – Thermodynamics vs. Heat Transfer; Applications of Heat Transfer; Heat and Other Forms of Energy; Specific Heat; Energy Transfer; The First Law of Thermodynamics; Control Volume; Surface Energy Balance; Heat Transfer Mechanisms: Conduction, Convection, and Radiation; Fourier’s Law of Heat Conduction; Thermal Conductivity; Classification of Convection; Newton’s Law of Cooling; Convection Heat Transfer Coefficient; Stefan-Boltzmann Law; Absorptivity in Radiation; Radiation between Surfaces; Problem Solving Technique.
2, 3	8	**Heat Conduction Equation** – Heat Transfer & Temperature; Transient vs. Steady; Multidimensional Heat Transfer; Heat Conduction Vector; One-Dimensional Heat Conduction Equations in a Large Plane Wall, in a Long Cylinder, and in a Sphere; Multi-Dimensional General Conduction Equations; Boundary Conditions in Heat Transfer; Solving Steady 1D Conduction Problems; Heat Generation in a Solid; Variable Thermal Conductivity.
4, 5	8	**Steady Heat Conduction** – Thermal Resistance Concept; Thermal Resistance Network in Plane Walls, in Cylinders, and in Spheres; Thermal Contact Resistance; Critical Radius of Insulation; Finned Surfaces; Boundary Conditions at Fin Base and Fin Tip; Fin Efficiency; Fin Effectiveness; Overall Effectiveness of Fins; Proper Length of a Fin; Heat Transfer in Common Configurations; Conduction Shape Factor.
6, 7	8	**Transient Heat Conduction** – Lumped System Analysis; Criteria for Lumped System Analysis; Biot Number; Spatial Effects; One-Term Approximation to Solution & Graphical Solution of the Transient 1D Heat Conduction Problem; Transient in Semi-Infinite Solids; Analytical Solution of the Transient 1D Heat Conduction Problem in a Semi-Infinite Medium; Product Solution of the Transient Conduction & Heat Transfer in Multi-Dimensional Systems.
8, 9, 10	10	**Numerical Methods in Heat Conduction** – 1D & 2D Finite Difference Method; Energy Balance Method; Mirror Image Concept; Implicit & Explicit

		Methods in Transient Heat Conduction; Stability Criterion for Explicit Method.
10	2	**Fundamentals of Heat Convection** – Nusselt Number; Classification of Fluid Flows; No-Slip Condition; Velocity Boundary Layer; Thermal Boundary Layer; Prandtl Number; Laminar & Turbulent Flows; Reynolds Number.
11, 12	8	**External Forced Convection** – Practical External Flows; Drag Coefficient & Friction Coefficient; Parallel Flow Over Flat Plates; Critical Reynolds Number; Average Values and Local Values of Friction Coefficient and Nusselt Number; Flow Across Cylinders & Spheres; Effect on Surface Roughness; Flow Across Tube Banks; Tube Arrangement; Heat Transfer by Tube Bank; Pressure Drop Across Tube Bank.
13, 14	8	**Internal Forced Convection** – Mean Velocity; Mean Temperature; Bulk Mean Fluid Temperature; Entrance Region; Fully Developed Region; Surface Thermal Conductions: Constant Surface Heat Flux, Constant Surface Temperature; Log Mean Temperature Difference (LMTD), Number of Transfer Units (NTU); Laminar and Turbulent Flows in Tubes; Some Empirical Correlations; Heat Transfer Enhancement in Tubes.

Contribution of course to meet the professional component:

This course prepares students to work professionally in the area of **Thermal Fluid Engineering and Energy**.

Relationship to EME programme objectives and outcomes:

This course primarily contributes to Electromechanical Engineering Programme outcomes that develop student abilities to:

(a) an ability to apply knowledge of mathematics, science, and engineering.
(e) an ability to identify, formulate, and solve engineering problems.

The course secondarily contributes to Electromechanical Engineering programme outcomes that develop student abilities to:

(l) an ability to use the computer/IT tools relevant to the discipline along with an understanding of their processes and limitations.

Course content:

Maths	Basic Sciences	Engineering Science	Engineering Design and Synthesis	Complementary Studies	Computer Studies	Total 100%
35	0	60	5	0	0	100

Persons who prepared this description:

Mr. Seng Kin Lao

Part B – General Course Information and Policies

2^{nd} Semester 2010/2011

Instructor: Mr. Seng Kin Lao
Office: N327C
Office Hour: By appointment
Phone: (853) 8397-4379
Email: skeltonl@umac.mo

Time/Venue:

TBA

Assessment:

Final assessment will be determined on the basis of:
Homework: 15%
Mid-term I: 30%
Final Exam (Comprehensive): 55%

Grading System:

The credit is earned by the achievement of a grade from 'A' to 'D'; 'F' carries zero credit.

Grades are awarded according to the following system:

Letter Grades	Grade Points	Percentage
A	4.0 (Excellent)	93-100
A-	3.7 (Very good)	88-92
B+	3.3	83-87
B	3.0 (Good)	78-82
B-	2.7	73-77
C+	2.3	68-72
C	2.0 (Average)	63-67
C-	1.7	58-62
D+	1.3	53-57
D	1.0 (Pass)	50-52
F	0 (Fail)	Below 50

Comment:

The objectives of the lectures are to explain and to supplement the text material. Students are responsible for the assigned material whether or not it is covered in the lecture. Students who wish to succeed in this course should read the assignments prior to the lecture and should work all homework assignments. You are encouraged to look at other sources (other texts, etc.) to complement the lectures and text.

Homework Policy:

The completion and correction of homework is a powerful learning experience; therefore:

- Homework is due one week after assignment unless otherwise noted, no late homework is accepted.
- Possible revision of homework grades may be discussed with the grader within one week from the return of the marked homework
- The homework grade will be based on the average of the assignment grades.

Quizzes/Mid-terms Exams:

One mid-term exam will be held during the semester.

Note:

- Recitation session is important part of this course and attendance is strongly recommended.
- No make-up exam is give except for CLEAR medical proof.

- No exam is given if you are 15 minutes late in the midterm exam and 30 minutes late in the final exam. Even if you are late in the exam, you must turn in at the due time.
- Cheating is absolutely prohibited by the university.

Appendix - Rubric for Programme Outcomes

Rubric for (a)	5 (Excellent)	3 (Average)	1 (Poor)
Understand the theoretic background	Students understand theoretic background and the limitations of the respective applications.	Students have some confusion on some background or do not understand theoretic background completely	Students do not understand the background or do not study at all
Use a correct model and formulation correctly	Students choose a model correctly and properly apply correct techniques	Students choose a wrong model sometime, use a wrong formula, or a different technique	Students use a wrong model and wrong formula, or do not know how to model
Compute the problem correctly	Students use correct techniques, analyze the problems, and compute them correctly	Students sometime solve problem mistakenly using wrong techniques	Students do not know how to solve problems or use wrong techniques completely

Rubric for (e)	5 (Excellent)	3 (Average)	1 (Poor)
Identify applications in engineering systems	Students understand problem and can identify fundamental formulation	Students understand problem but cannot apply formulation.	Students cannot identify correct terms for engineering applications
Modeling, problem formulation and problem solving	Students choose and properly apply the correct techniques	Students model correctly but cannot select proper technique or model incorrectly but solve correctly accordingly	Students at loss as to how to solve a problem

Rubric for (l)	5 (Excellent)	3 (Average)	1 (Poor)
Use modern computer and software tools in engineering practice	Student uses the computer and software to correctly analyze engineering problems and/or create engineering designs, and understands the limitations of the software.	Student uses the computer and software to correctly analyze engineering problems and/or create engineering designs.	Student does not use the computer and software to correctly create engineering designs and/or does not correctly interpret the results.