McMaster University
Dept. of Mechanical Engineering

ME 4V03 – THERMO-FLUIDS SYSTEMS DESIGN AND ANALYSIS

Fall 2020

OBJECTIVES/RATIONALE: *The objective of the course is to integrate material learnt in prior themo-fluid courses, and to provide students with an introduction to system-oriented design methods. The design, operation and performance of mechanical equipment commonly used in thermo-fluid systems will be reviewed. Methods in system simulation and optimization will be introduced. Prior courses in Thermodynamics, Fluid Mechanics and Heat Transfer are a prerequisite for this course.*

LEARNING OUTCOMES: Upon successful completion of the course the students will be expected to have demonstrated the ability to:

1. Analyze fluid systems and design piping systems and select appropriate pumps.
2. Analyze and select heat exchangers for thermal systems.
3. Perform system analysis and obtain performance characteristics of common thermal systems.
4. Model and perform system simulation of thermal systems.
5. Optimize thermal system performance under different constraints.
6. Integrate exergy analysis into system performance.

INSTRUCTOR: Dr. M. Alavy
Office: N/A
email: *alavyghs@mcmaster.ca*

LECTURES: Monday 12:30 – 13:20
Tuesday 13:30 – 14:20
Thursday 12:30 – 13:20

TUTORIAL: Tuesday 15:30 – 14:20

OFFICE HOURS: Contact me and/or TAs by email to ask your questions or schedule an online meeting.

HOMEWORK
Homework problem-solving is an essential element of this course. Individual work is required on all problems. Over the course of the semester, 10 homework sets are planned. Homework is due by 4:00 p.m. on the date assigned. Late submissions will not be accepted. Solutions to the homework will be posted on the course site on AVENUE.

TESTS AND EXAMINATIONS
There will be two take-home midterm tests and a take-home final examination. The material to be covered in each test and exam will be cumulative.

GRADING SYSTEM

Final grades will be determined by the following weighting of homework, tests and final exam.

Homework	10%
Test I	20%
Test II	20%
Final Exam	50%
Final Grade	***100%***

ACADEMIC INTEGRITY

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity. **It is your responsibility to understand what constitutes academic dishonesty.**

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university. For information on the various types of academic dishonesty please refer to the *Academic Integrity Policy*, located at https://secretariat.mcmaster.ca/university-policies-procedures-guidelines/

The following illustrates only three forms of academic dishonesty:

- plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
- improper collaboration in group work.
- copying or using unauthorized aids in tests and examinations.

COURSES WITH AN ON-LINE ELEMENT

Some courses may use on-line elements (e.g. e-mail, Avenue to Learn (A2L), LearnLink, web pages, capa, Moodle, ThinkingCap, etc.). Students should be aware that, when they access the electronic components of a course using these elements, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course. The available information is dependent on the technology used. Continuation in a course that uses on-line elements will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure please discuss this with the course instructor.

CONDUCT EXPECTATIONS

As a McMaster student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the Code of Student Rights & Responsibilities (the "Code"). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, whether in person or online.

It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery), will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students' access to these platforms.

ACADEMIC ACCOMMODATION OF STUDENTS WITH DISABILITIES

Students with disabilities who require academic accommodation must contact Student Accessibility Services (SAS) at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make arrangements with a Program Coordinator. For further information, consult McMaster University's Academic Accommodation of Students with Disabilities policy.

REQUESTS FOR RELIEF FOR MISSED ACADEMIC TERM WORK

McMaster Student Absence Form (MSAF): In the event of an absence for medical or other reasons, students should review and follow the Academic Regulation in the Undergraduate Calendar "Requests for Relief for Missed Academic Term Work".

ACADEMIC ACCOMMODATION FOR RELIGIOUS, INDIGENOUS OR SPIRITUAL OBSERVANCES (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the RISO policy. Students should submit their request to their Faculty Office normally within 10 working days of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

COPYRIGHT AND RECORDING

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, including lectures by University instructors

The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.

Course Outline

1. Review of Piping Systems, Pumps and Compressors
- 1.1 Fundamental Equations, Friction Factors, Head Losses
- 1.2 Valves and Fittings
- 1.3 Types of Pumps and Pump Characteristics
- 1.4 Cavitation and Net Positive Suction Head
- 1.5 Pump-System Operation

2. Heat Exchangers
- 2.1 Review of Heat Transfer
- 2.2 Types of Heat Exchangers
- 2.3 Analysis of Heat Exchangers

3. Power Generation Systems
- 3.1 Review of Thermodynamics
- 3.2 Vapor Power Systems
- 3.3 Gas Power Systems
- 3.4 Other Power Systems

4. Exergy Analysis
- 4.1 Exergy of Systems
- 4.2 Closed and Open System Exergy Balance
- 4.3 Exergetic Efficiency
- 4.4 Thermoeconomics

5. Thermal Systems Design
- 5.1 The Design Process
- 5.2 Life-Cycle Design
- 5.3 Thermal System Design Aspects
- 5.4 Environmental, Safety and Reliability Aspects

6. System Simulation and Optimization
- 5.5 Modeling Thermal Equipment
- 5.6 Description of System Simulation
- 5.7 Methods of Simulation
- 5.8 Simulation of Thermal Systems
- 5.9 Optimization Procedures

7. Design Optimization and System Performance Evaluation
- 5.10Thermodynamic Optimization
- 5.11Economic Optimization
- 5.12Design Evaluation
- 5.13Performance Evaluation

Suggested Texts

Introduction to Fluid Mechanics, Fox, R.W., McDonald, A.T and Pritchard, P.J.
Fundamentals of Engineering Thermodynamics, M. Moran and H. Shapiro.
Introduction to Heat Transfer, Incropera, F.P., Dewitt, D.P.
Design and Optimization of Thermal Systems, Jaluria, Y.
Thermal Design and Optimization, Bejan, A., Tsatsaronis, G. and Moran, M., J.
Design of Fluid Thermal Systems, Janna, W.S.
Design of Thermal Systems, Stoecker, W.F.

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NOTES ON HOMEWORK SOLUTIONS

Homework policies/procedures

1. Homework is due by 4:00 p.m on the date assigned.
   Late submissions will not be accepted.

2. Solutions to the Homework problems will posted on the course site on AVENUE.

3. Performance on homework assignments comprise 10% of a student's final grade; consequently individual work is required on all homework problems. Students are encouraged to discuss with one another the general principles involved in the homework sets, but solutions to each problem must be attempted individually. Duplicate solutions indicating copying among students will be considered cheating and will be dealt with strictly.

Homework format

1. Use 8-1/2 x 11 paper, and write on one side only.

2. Start each problem on a new page.

3. Clearly label each step of the solution (KNOWN, FIND, SCHEMATIC, ASSUMPTIONS , ANALYSIS etc.)

4. Develop the analysis as far as possible before substituting numerical values.
   If possible, give the answer algebraically before computing the final numerical answer.

5. Clearly indicate your final answer.
   Be sure to include appropriate units.

6. Attach a listing of any computer program(s) used in the solution.

Homework grading

Most problems will be graded on a 10-point scale, with points awarded in the following typical distribution.

Use of proper paper, format;steps clearly labeled	1
Schematic, complete with appropriate control volume	1
Appropriate assumptions	1
Clearly-developed and correct analysis	5
Algebraic solution (if possible)	1
Numerical result (if required), with appropriate units	1

	Thermo-Fluids Systems Design and Analysis - Fall 2020	
DATE	**TOPIC**	
Tue Sep 08	Introduction, Review Piping Systems	
Thu Sep 10	Fluid Machinery	
Mon Sep 14	Turbomachinery Analysis/Euler Turbomachine Equation	
Tue Sep 15	Performance Characteristics	
Thu Sep 17	Fluid Systems	
Mon Sep 21	Review/Heat Transfer Fundamentals	
Tue Sep 22	Double Pipe Heat Exchangers	
Thu Sep 24	Shell and Tube Heat Exchangers	
Mon Sep 28	Design of Heat Exchangers	
Tue Sep 29	Review/Thermodynamic Principles	
Thu Oct 01	Vapor Power Systems, Rankine Cycles	
Mon Oct 05	Superheat and Reheat /Regenerative Vapor Power Cycles, Binary Cycles	
Tue Oct 06	Gas Power Systems, Internal Combustion Engines	
Thu Oct 08	Otto and Diesel Cycles/Air-Standard Dual Cycle	
Mon Oct 19	**MID TERM TEST I**	
Tue Oct 20	Gas Turbines, The Brayton Cycle	
Thu Oct 22	Regenerative Gas Turbines	
Mon Oct 26	Gas Turbines for Aircraft Propulsion	
Tue Oct 27	Vapor-Compression Refrigeration Cycles	
Thu Oct 29	Heat Pumps, Gas Refrigeration Systems	
Mon Nov 02	Exergy of Systems	
Tue Nov 03	Exergy Balance	
Thu Nov 05	Exergetic Efficiency	
Mon Nov 09	Thermoeconomics	
Tues Nov 10	Thermal System Design	
Thu Nov 12	Design Considerations/Codes and Standards	
Mon Nov 16	Modeling Thermal Equipment	
Tue Nov 17	Overview of System Simulation	
Thu Nov 19	Methods of System Simulation	
Mon Nov 23	**MID TERM TEST II**	
Tue Nov 24	System Simulation Programs	
Thu Nov 26	System Optimization	
Mon Nov 30	Optimization Procedures	
Tue Dec 01	Lagrange Multiplier Methods	
Thu Dec 03	Review	
Mon Dec 07	Review	
Tue Dec 08	Review	