

McMaster University
Dept. of Mechanical Engineering

ME 4V03 – THERMO-FLUIDS SYSTEMS DESIGN AND ANALYSIS

Fall 2023

OBJECTIVES/RATIONALE: *The objective of the course is to integrate material learnt in prior thermo-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. C.Y. Ching
Office: JHE103
Phone: 905 525 9140 ext. 24998
email: chingcy@mcmaster.ca

LECTURES: Tuesday 12:30PM – 1:20PM
Wednesday 12:30PM – 1:20PM
Friday 12:30PM – 1:20PM

TUTORIAL: Tuesday 11:30AM – 12:20PM

OFFICE HOURS: Tuesday and Wednesday 1:30PM – 2:30PM.

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 11:59 p.m. on the date assigned. Late submissions will not be accepted.

TESTS AND EXAMINATIONS

There will be two mid term tests and a 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%
<i>Final Grade</i>	<u>100%</u>

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

- 6.1 Modeling Thermal Equipment
- 6.2 Description of System Simulation
- 6.3 Methods of Simulation
- 6.4 Simulation of Thermal Systems
- 6.5 Optimization Procedures

7. Design Optimization and System Performance Evaluation

- 7.1 Thermodynamic Optimization
- 7.2 Economic Optimization
- 7.3 Design Evaluation
- 7.4 Performance 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.

ME 4V03 – THERMO-FLUIDS SYSTEMS DESIGN AND ANALYSIS

NOTES ON HOMEWORK SOLUTIONS

Homework policies/procedures

1. Homework is due by 11:59PM on the date assigned. Homework must be submitted online to AVENUE. 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. A legible PDF of the solutions must be submitted. Make sure your name, MAC ID and student number is on the first page of the solutions.
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.

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

Thermo-Fluids Systems Design and Analysis - Fall 2023		
PERIOD	DATE	TOPIC
1	Tue Sep 05	Introduction to Thermal System Design
2	Wed Sep 06	Review Piping Systems
3	Fri Sep 08	Fluid Machinery
4	Tue Sep 12	Turbomachinery Analysis/Euler Turbomachine Equation
5	Wed Sep 13	Performance Characteristics
6	Fri Sep 15	Fluid Systems
7	Tue Sep 19	Review/Heat Transfer Fundamentals
8	Wed Sep 20	Double Pipe Heat Exchangers
9	Fri Sep 22	Shell and Tube Heat Exchangers
10	Tue Sep 26	Design of Heat Exchangers
11	Wed Sep 27	Review/Thermodynamic Principles
12	Fri Sep 29	Vapor Power Systems, Rankine Cycles
13	Tue Oct 03	Superheat and Reheat /Regenerative Vapor Power Cycles, Binary Cycles
14	Wed Oct 04	Gas Power Systems, Internal Combustion Engines
15	Fri Oct 06	Otto and Diesel Cycles/Air-Standard Dual Cycle
16	Tue Oct 17	MID TERM TEST I [6:30PM to 8:00PM]
17	Wed Oct 18	Gas Turbines, The Brayton Cycle
18	Fri Oct 20	Regenerative Gas Turbines
19	Tue Oct 24	Gas Turbines for Aircraft Propulsion
20	Wed Oct 25	Vapor-Compression Refrigeration Cycles
21	Fri Oct 27	Heat Pumps, Gas Refrigeration Systems
22	Tue Oct 31	Exergy of Systems
23	Wed Nov 01	Exergy Balance
24	Fri Nov 03	Exergetic Efficiency
25	Tue Nov 07	Thermoeconomics
26	Wed Nov 08	Thermal System Design
27	Fri Nov 10	Design Considerations/Codes and Standards
28	Tue Nov 14	Modeling Thermal Equipment
29	Wed Nov 15	Overview of System Simulation
30	Fri Nov 17	Methods of System Simulation
31	Tue Nov 21	MID TERM TEST II [6:30PM to 8:00PM]
32	Wed Nov 22	System Simulation Programs
33	Fri Nov 24	System Optimization
34	Tue Nov 28	Optimization Procedures
35	Wed Nov 29	Lagrange Multiplier Methods
36	Fri Dec 01	Review
37	Tue Dec 05	Review
38	Wed Dec 06	Review

COURSE OUTLINE – APPROVED ADVISORY STATEMENTS

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](https://secretariat.mcmaster.ca/university-policies-procedures-guidelines/), 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.

AUTHENTICITY / PLAGIARISM DETECTION

Some courses may use a web-based service (Turnitin.com) to reveal authenticity and ownership of student submitted work. For courses using such software, students will be expected to submit their work electronically either directly to Turnitin.com or via an online learning platform (e.g. Avenue to Learn, etc.) using plagiarism detection (a service supported by Turnitin.com) so it can be checked for academic dishonesty.

Students who do not wish their work to be submitted through the plagiarism detection software must inform the Instructor before the assignment is due. No penalty will be assigned to a student who does not submit work to the plagiarism detection software. **All submitted work is subject to normal verification that standards of academic integrity have been upheld** (e.g., on-line search, other software, etc.). For more details about McMaster's use of Turnitin.com please go to www.mcmaster.ca/academicintegrity.

COURSES WITH AN ON-LINE ELEMENT

Some courses may use on-line elements (e.g. e-mail, Avenue to Learn, 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.

ONLINE PROCTORING

Some courses may use online proctoring software for tests and exams. This software may require students to turn on their video camera, present identification, monitor and record their computer activities, and/or lock/restrict their browser or other applications/software during tests or exams. This software may be required to be installed before the test/exam begins.

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

In the event of an absence for medical or other reasons, students should review and follow the [Policy on Requests for Relief for Missed Academic Term Work](#).³

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

³ Updated to the [Policy on Requests for Relief for Missed Academic Term Work](#) effective May 1, 2021

communication channels, such as McMaster Daily News, Avenue to Learn and/or McMaster email.

STUDENT SUPPORTS

WELLNESS

Student Wellness Centre

On-Campus Support for Medical and Mental Health Concerns. Doctors and Counsellors available. Located in PGCL, 2nd Floor.

Mon-Fri 9AM-5PM 905-525-9140 ext. 27700
<https://wellness.mcmaster.ca/contact-us/>

Main St. West Urgent Care Centre

For immediate health concerns that do not require the emergency room.

690 Main St W - Mon-Sun 9AM-9PM

Emergency Rooms

For **immediate, serious** health concerns.

St. Joseph's Healthcare Hamilton
50 Charlton Ave E

McMaster Children's Hospital
Students 17 and under

Telehealth Ontario

Telehealth Ontario is a free, confidential service you can call to get health advice or information. A Registered Nurse will take your call 24 hours a day, seven days a week.

Toll-free: 1-866-797-0000 Toll-free TTY: 1-866-797-0007

Phone Lines

Good2Talk

Confidential helpline providing professional counselling, info and referrals for mental health, addiction, and well-being

1-866-925-5454

LGBT Youthline

Confidential, non-judgemental & informed LGBTQQ2SI peer support.

Sun-Fri, 4-9:30 PM, Text 647-694-4275

SACHA (SEXUAL ASSAULT CENTRE - HAMILTON AREA)

Confidential, anonymous 24-hour nonjudgmental telephone support for adults who have experienced sexual violence at any point in their lives; will provide accompaniment to hospital or police station for survivors wishing to seek medical attention or report; counselling services & public education

905-525-4162

Empower Me (Graduate Students)

24/7 accessible counselling services to empower you to thrive, crisis support, mental health and well-being services.

1-844-741-6389

Bounceback

CBT skills-building for mild to moderate depression and anxiety for people 15 or older. If accessed through self-referral, the client's primary care provider will be notified.

1-866-345-0224

INDIGENOUS STUDENTS

Indigenous Student Services

Academic & social counselling, employment aid
LRW 1010

ext. 23788

indigenous.admin@mcmaster.ca
indigenous.mcmaster.ca

INTERNATIONAL STUDENTS

International Student Services

Advising services for international students and exchange students
GH 104

ext. 24254

iss@mcmaster.ca
iss.mcmaster.ca

STUDENT SUPPORTS

ACADEMIC

Student Success Centre

Academic skills assistance, job search, volunteering
GH 110
ext. 24254
studentsuccess@mcmaster.ca

Student Accessibility Services

Disability services, assistive technology support
MUSC B107
ext. 28652
sas@mcmaster.ca

TutorOcean

Student to Student Tutoring Services
<https://mcmaster.tutorocean.com/>

FINANCIAL

Office of Student Financial aid and Scholarships

Emergency funding, government funds, OSAP assistance, scholarships, work programs
GH 120
ext. 24319
<https://registrar.mcmaster.ca/aid-awards/>

FOOD

Food Collective Centre (FKA Mac Bread Bin)

The Food Collective Centre is a service run by students dedicated to cultivating stronger food systems in the McMaster and surrounding community. (MSU Service)
macbreadbin@msu.mcmaster.ca
<https://www.msumcmaster.ca/services-directory/14-food-collective-centre>

Neighbour 2 Neighbour

Food bank, community kitchen, community counselling, help with paying for utilities, and more. Hamilton Mountain.
905-574-1334 <http://www.n2ncentre.com/>

CRISIS SUPPORT

Barrett Centre for Crisis Support

Provides a safe environment in the community and responds to the needs of individuals, 16 years of age or older, who experience a mental health crisis and do not require a hospital stay. Confidential and free services 24/7/365
24 Hour Crisis Line: 905-529-7878, Toll Free: 1-844-777-3571

COAST (Crisis Outreach and Support Team)

Hamilton's crisis line is answered 24 hours a day, 7 days a week. The COAST mobile team, consisting of a mental health worker, and a police officer, will respond to crisis calls between the hours of 8 a.m. and 1 a.m. daily.
905-972-8338

Oakville Distress Centre

Distress Centre Halton provides telephone and online support to people to better cope with crisis, loneliness, and emotional stress. Also serves the Hamilton area.
905-849-4541

Assaulted Women's Helpline

Free, anonymous and confidential telephone and TTY crisis telephone line to all women in the province of Ontario who have experienced any form of abuse. Provides crisis counselling, safety planning, emotional support, information and referrals accessible 24/7/365.
Toll-free: 1-866-863-0511 TTY: 1-866-863-7868

Crisis Resources in the GTA

The CAMH Distress Crisis Resources web page lists a number of phone lines, response teams and hospitals in the GTA.
<https://www.camh.ca/en/health-info/crisis-resources>

STUDENT SUPPORTS

OTHER

Student Assistance Plan (Undergraduate)

Psychological counseling (offered in-person, over the phone, or over secure video) and academic-life services (legal consultation, financial consultation, life coaching, nutrition consultation and wellness resources offered virtually or in-person)

<https://www.msumcmaster.ca/services-directory/36-health-and-dental-insurance/student-assistance-plan>

Ombuds Office

Advice for students, staff, and faculty regarding academic and non-academic concerns.

MUSC 210

ext. 24151

ombuds@mcmaster.ca

mcmaster.ca/ombuds

SWHAT - Walk Safe Program

The Student Walk Home Attendant Team (SWHAT) is a volunteer service within the McMaster Students Union that will walk or bus with students during the evening hours 7 days a week, in all kinds of weather! (MSU Service)

Ext. 27500

swhat@msu.mcmaster.ca

Student Support and Case Management

Student rights & responsibilities

GH 207

ext. 23845

studentconduct.mcmaster.ca

Chaplaincy Centre

Pastoral support with personal counselling and bereavement support groups.

MUSC 231

ext. 24207

McMaster Engineering Society

Support from other McMaster Engineering Students

<https://www.macengsociety.ca/>

MSU PEER SUPPORT SERVICES

MSU Maccess

Maccess is a service that aims to build and maintain a campus that celebrates, advocates, and ensures inclusivity in the area of disability. A central aspect to Maccess is the provision of peer support by trained volunteers with lived experiences with disability such as chronic illness, mental illness, mental health concerns, neurodivergence, and additional identities.

Student Health Education Centre

SHEC is a peer-run health promotion, education, and referral service for McMaster University students. SHEC focuses on engaging with students about health-related issues through performances, peer support, fundraisers, and events. The service offers peer support, anonymous and confidential pregnancy testing, a resource library, condoms, lubricant, and menstrual products. SHEC's space is located in MUSC 202.

Women + Gender Equity Network

WGEN is a service that caters to women, transfolk, people who identify outside the gender binary, and all survivors of sexual assault. WGEN provides a safe(r) space and resource library on campus in MUSC 204. Volunteers in the space offer peer support and the service also runs a support group for survivors of domestic and intimate partner violence.

Pride Community Centre

The Pride Community Centre is a service of the McMaster Students Union. We provide a contact point for McMaster students that may identify as gay, lesbian, bisexual, transgender, queer, and/or any of the other diverse identities that make up our community. We offer educational programming and access to resources of interest, as well as peer support and a physical space for students to meet and socialize with each other. As advocates for gender & sexual diversity, the PCC's mandate upholds that LGBTQ+ students are entitled to a safe and supportive campus, absent of homophobia and transphobia, where the expression of one's gender & sexual identity is welcomed and respected.