

ME 4Q03 / 6Q03
Mechanical Vibrations
Fall 2022
Course Outline

COURSE DESCRIPTION

This course provides students with an introduction to the fundamental concepts of mechanical vibrations and covers transient and steady state vibration of single- and multi-degree of freedom systems. Free and forced vibrations of single and multiple degree-of-freedom mechanical systems, transient response, damping and vibration isolation.

During this course students will gain an appreciation for harmonic motion as well as the modeling of mechanical systems. This course will draw on the math skills established in previous courses with a special emphasis on understanding the physical phenomena involved as well as being able to interpret and apply the results to solve real problems.

PRE-REQUISITES

Prerequisite(s): ENGINEER 2Q04 or MECHENG 2Q04 or 2QA4 and registration in any Mechanical Engineering or Mechatronics program

INSTRUCTOR OFFICE HOURS AND CONTACT INFORMATION

Dr. Stephen Veldhuis
MMRI in The Portal@MIP
veldhu@mcmaster.ca
905 525 9140 ext. 27044

Office Hours:
Generally, Tuesdays – 1:30-2:30 pm
Or by appointment (preferably MS Teams)

TEACHING ASSISTANT OFFICE HOURS AND CONTACT INFORMATION

Hosna Geraei

geraeih@mcmaster.ca

Eden Lazar

ausatoue@mcmaster.ca

Mohsen Chegini

cheginim@mcmaster.ca

**Aksahay
Manikandan**

manikaa@mcmaster.ca

Yunzhe (Will) Yang

yangy489@mcmaster.ca

COURSE WEBSITE

<https://avenue.mcmaster.ca/>

MATERIALS

Required Texts:

Mechanical Vibrations 6th ed. S. Rao, Prentice Hall

A limited number of hard copies are available at the bookstore.

Calculator:

Only the McMaster Standard Calculator will be permitted in tests and examinations. This calculator is available for purchase at the McMaster Campus Store.

COURSE FORMAT AND EXPECTATIONS

The course is organized as follows:

- 3 classroom-based lectures per week
- In class quizzes
- 3 midterm tests
- Fall break Oct. 10-15
- Final exam scheduled by the registrar's office
- ME6Q03 students – course project

COURSE SCHEDULE

| # | Topic | Text Section | Text Pages | Text Problems |
|-----------|--|------------------|-----------------------------|--|
| 1 | Introduction to mechanical vibrations | 1.1-1.3 | 1-15 | 1.2 |
| 2 | Definitions and Terms | 1.4-1.5 | 15-19 | 1.4, 1.6 |
| 3 | Modeling and Basic Elements - Springs - Part I | 1.6, 1.7 | 20-31 | 1.7 |
| 4 | Basic Elements - Springs - Part II | 1.7 | 32-41 | 1.11, 1.15, 1.40, 1.47 |
| 5 | Basic Elements - Mass and Damping | 1.8-1.9 | 41-55 | 1.46, 1.50, 1.73 |
| 6 | Lumped Mass and Harmonic Motion | 1.10, | 55-64 | 1.91, 1.92, 1.93, 1.99 |
| 7 | Beating and Free Vibration | 1.10, 2.1-2.2 | 64, 125- 147 | 1.122, 2.4, 2.6 |
| 8 | Natural Frequency and Examples | 2.3 | 148- 153 | 2.10, 2.27, 2.93, 2.94 |
| 9 | Energy Method | 2.2.2 | 131- 132 | 2.47, 2.48 |
| R1 | Midterm 1 Review | | | 1.1, 1.8, 1.9, 1.16, 1.26, 1.30, 1.31, 1.52, 1.53, 1.54, 1.74, 1.100, 2.7, 2.9, 2.12, 2.25, 2.90, 2.92 |
| M1 | MIDTERM I | | | |
| 10 | Solutions to 1DOF and COP | 2.2, 2.3 | 133- 139, 152- 153 | 2.96, 2.97 |
| 11 | Damped System Response | 2.6 | 160- 179 | 2.138, 2.140, 2.158 |
| 12 | Forced Vibration | 3.1-3.3 | 269- 281 | 3.9, 3.11, 3.25 |
| 13 | Forced Vibration with Damping | 3.4 | 281- 289 | 3.30, 3.47 |

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|---------------------|---|-------------------------|-----------------------------|--|
| 14 | Base Excitation | 3.6 | 292- 298 | 3.61, 3.62 |
| Fall Break | | | | |
| 15 | Base Excitation - Part II - Truck Example | 3.6 | 292- 298 | 3.58, 3.64 |
| 16 | Rotating Unbalance | 3.7 | 298- 304 | 3.77, 3.78 |
| 17 | Rotating Unbalance Example with Force Transmitted | 3.6.1 | 294- 295 | 3.82, 3.84 |
| R2 | Midterm 2 Review | | | 2.98, 2.142, 2.147, 3.24, 3.29, 3.34, 3.38, 3.45, 3.55, 3.57, 3.72, 3.76, 3.80 |
| M2 MIDTERM 2 | | | | |
| 18 | Vibration Isolation Example | 9.10, | 823- 844 | 9.27, 9.32, 9.40 |
| 19 | Shaft Whirl and Sensors | 9.5, 10.1- 10.3.3 | 807- 813, 896- 913 | 9.21, 10.1 |
| 20 | Stability - Machining | 2.11, 3.11 | 203- 207, 312- 324 | 2.186 |
| 21 | General Forcing Functions - Transfer Function and Laplace | 3.12- 3.13, 4.7 | 324- 331, 418- 439 | 3.105, 3.109, 4.60 |
| 22 | 2 DOF Systems | 5.1-5.2 | 481- 487 | 5.1, 5.3 |
| 23 | 2 DOF Modes and Natural Frequencies | 5.3 | 488- 496 | 5.8, 5.9 |
| 24 | 2 DOF Examples | 5.3-5.4 | 481- 502 | 5.16, 5.38 |
| 25 | Static and Dynamic Coupling and Forced Vibration | 5.5, 5.6 | 502- 511 | 5.41, 5.42 |
| 26 | Multi DOF Systems & Energy Method for Multi DOF | 6.1- 6.3, 6.7 | 568- 577, 592- 596 | 6.1, 6.32, 6.44 |
| 27 | Dynamic Vibration Absorber | 9.11 | 855- 867 | 9.68, 9.80 |
| 28 | Continuous Systems | 8.1, 8.2 | 717- 728 | 8.3, 8.14 |

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|-----------|-----------------------------|----------|---------|--|
| 29 | Continuous Systems Examples | 8.1, 8.2 | 717-728 | 8.7, 8.15 |
| R3 | Midterm 3 Review | | | 5.2, 5.4, 5.11, 5.21, 5.36, 5.37, 5.40, 5.43, 5.46, 5.52, 6.3, 6.5, 6.34, 6.36, 6.46, 6.48, 9.30, 9.33, 9.67, 9.70, 8.6, 8.8 |
| R4 | Midterm 3 Review | | | |
| R5 | Midterm 3 Review | | | |
| M3 | MIDTERM 3 | | | |
| R6 | Exam Review | | | 1.3, 1.10, 1.27, 1.48, 1.51, 1.56, 1.101, 2.5, 2.13, 2.15, 2.28, 2.44, 2.91, 2.95, 2.141, 3.10, 3.19, 3.35, 3.46, 3.58, 3.63, 3.83, 3.85, 5.5, 5.7, 5.22, 5.44, 6.2, 6.4, 6.33, 6.35, 6.45, 6.47, 8.6, 8.8, 8.13, 9.31, 9.34, 9.63, 9.66, 9.73, 9.76 |
| R7 | Final Exam Review | | | |
| R8 | Final Exam Review | | | |
| R9 | Final Exam Review | | | |

| ASSESSMENT | | |
|------------|--|--------|
| Component | Due Date | Weight |
| Quizzes | In class (complete 80% with 50% score) | 10% |
| Midterm 1 | Tues. Sept. 27, 7:00-9:00pm in LRW B1007 | 15% |
| Midterm 2 | Tues. Oct. 25, 7:00-9:00pm in LRW B1007 | 15% |
| Midterm 3 | Tues. Nov. 29, 7:00-9:00pm in LRW B1007 | 15% |
| Final Exam | Scheduled by the registrar's office | 45% |
| Total | | 100% |

For ME6Q03 course project represents 30% of final grade. Discuss the project topic at the start of term.

ACCREDITATION LEARNING OUTCOMES

The Learning Outcomes defined in this section are measured for Accreditation purposes only and will not be directly taken into consideration in determining a student's grade in the course.

| Outcomes | Indicators |
|--|---|
| Be able to describe dynamic systems using accurate terminology | Knowledge Base for Eng. (1.3, 1.4) |
| Model a dynamic system as a collection of masses, springs and dampers | Problem Analysis (2.1, 2.2) |
| Develop and solve the equation of motion for a dynamic system | Knowledge Base for Eng. (1.1) |
| Comment on dynamic behaviour in terms of natural frequency and amplitude of vibration for both free and forced vibration cases | Investigation (3.1, 3.2) |
| Assess the implications of changing mass, stiffness and damping on system behaviour and performance | Problem Analysis (2.1, 2.2) |
| Analyze general forcing conditions, apply them to a system and solve for the system response | Investigation (3.1, 3.2) |
| Model and solve for natural frequencies and mode shapes of multi degree of freedom systems | Knowledge Base for Eng. (1.1, 1.3, 1.4) |
| Solve continuous systems for natural frequencies, mode shapes and nodes | Knowledge Base for Eng. (1.1, 1.3, 1.4) |
| Be able to make design recommendations that will improve system performance | Design (4.1, 4.2, 4.3) |

For more information on Accreditation, please visit: <https://www.engineerscanada.ca>

EQUITY, DIVERSITY, AND INCLUSION

Every registered student belongs in this course. Diversity of backgrounds and experiences is expected and welcome. You can expect your instructor to be respectful of this diversity in all aspects of the course, and the same is expected of you.

The Department of Mechanical Engineering is committed to creating an environment in which students of all genders, cultures, ethnicities, races, sexual orientations, abilities, and socioeconomic backgrounds have equal access to education and are welcomed and treated fairly. If you have any concerns regarding inclusion in our Department, in particular if you or one of your peers is experiencing harassment or discrimination, you are encouraged to contact the Chair, Associate Undergraduate Chair, Academic Advisor or to contact the [Equity and Inclusion Office](#).

PHYSICAL AND MENTAL HEALTH

For a list of McMaster University's resources, please refer to the [Student Wellness Centre](#).

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:

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

ON-LINE

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 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, MS Teams 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.

COURSE POLICY ON MISSED WORK, EXTENSIONS, AND LATE PENALTIES

1. It is the students' responsibility to regularly check the course webpage (ex. Avenue to Learn) for updates and announcements.
2. Completing 80% of the Quizzes with a score of 50% constitutes 10/10 for the quiz grade.
3. Missed midterms will automatically have the grade weight shifted to the final exam.
4. Special situations can be discussed with the course instructor.

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.

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.