### Vm240: Introduction to Dynamics and Vibrations Yongxing Shen Summer 2017

# What is dynamics?

- The study of the motions of bodies and the forces that accompany or cause those motions.
  - Kinematics: The branch of dynamics that deals with only space and time.
  - Kinetics: The branch of dynamics that deals with the relationships between forces and motions.
- Governing laws: Newton's laws of motion

### What subjects will we encounter?





[HLY]

[HLY]

### **Example application 1**



Human-Safe Co-Robots for Manufacturing Source: <u>https://disl.osu.edu/</u> Credit: Haijun Su, Ohio State University

### **Example application 2**



200 MPH = 320 km/h 500 miles = 800 km

# A brief history

- Newton: The 3 laws of motion, law of universal attraction
- ▶ 18<sup>th</sup> century:
  - Bernoulli: Principle of virtual work
  - D'Alambert: D'Alambert's principle
  - Euler: Rigid body dynamics
- ▶ 19<sup>th</sup> century:
  - Lagrange, Poisson, Hamilton, & Jacobi: Analytical mechanics (rational mechanics) – a much richer mathematical structure for Newtonian mechanics
- > 20<sup>th</sup> century:
  - Limits of Newtonian mechanics found: Systems moving at speeds comparable with the speed of light, or systems of dimensions comparable to the size of the atom

# What is vibration?

- The branch of dynamics that deals with periodic or oscillatory motion. Examples:
  - Response of civil engineering structures to dynamic loading, ambient conditions and earthquakes
  - Vibration of unbalanced rotating machines
  - Vibration of power lines due to wind excitation
  - Aircraft wings

# Contents

#### Dynamics

- Particle kinematics (review)
- Particle kinetics (review)
- Rigid body kinematics
- Rigid body kinetics
- Vibrations
  - Free vibration of a single degree of freedom
  - Damped vibration of a single degree of freedom
  - Forced vibration of a single degree of freedom
  - Vibration of systems with two degrees of freedom

### **Reference** texts

Textbooks:

- [MK] David J. McGill and Wilton W. King, Engineering Mechanics: An Introduction to Dynamics, 4<sup>th</sup> Ed., Tichenor Publishing, 2013
- [W] Magd Abdel Wahab, Dynamics and Vibration, Revised 1st Ed., Wiley, 2008 (Ch. 6-8 only)
- References

- [BF] Anthony Bedford and Wallace Fowler, Engineering Mechanics: Dynamics, Pearson, 2008
- [KP] N. Jeremy Kasdin and Derek A. Paley, Engineering Dynamics: A Comprehensive Introduction, Princeton University Press, 2011
- [WDG] Sheila Widnall, John Deyst, Edward Greitzer, Dynamics, MIT Open CourseWare, Fall 2009

# Where do we fit in JI's ME curriculum?



# Prerequisite: Vp140/Vp160

- It is assumed that you have mastered the following topics:
  - Classical mechanics, including vectors, motion in one dimension, circular motion, projectile motion, relative velocity and acceleration, Newton's laws, particle dynamics, work and energy, linear momentum, torque, angular momentum of a particle, simple harmonic motion, gravitation, and planetary motion (taken from the description of Vp140)

# Advice on taking this course

- Make sure you have access to, and can receive announcements from, Canvas
- Pay attention to details, especially to similar but different notations
  - Example: The gradient operator (\$\vec{P}\$) and the divergence operator (\$\vec{P}\$ ·) have different notations, and both can be applied to vector fields. Moreover, the dot in (\$\vec{P}\$ ·) is "\cdot", not the period on the keyboard.
- Be ready to think in an abstract way and handle extensive mathematical derivations
- Be skeptical on all materials
- Have fun!

#### Grading policy Grading policy



Homework/quizzes/lab

attendance (25%)

Midterm exam (30%)

Final exam (45%)

- One (1) double-sided A4-sized sheet of notes is permitted for the midterm exam (June 16).
- Two (2) double-sided A4-sized sheets of notes are permitted for the final exam (in the week of Aug. 7).

# Specific requirements on the homework assignments

- Submit in hardcopy
- Printed submissions are preferred. Hand-written submissions must be clearly written.
- Any result obtained from a computer program (e.g., Mathematica) must accompany the original code or input (electronic or printed), or the corresponding result receives zero (0) mark.
- Late submission policy

- Late by within 24 hours: 20% penalty
- Late by within 48 hours: 40% penalty
- Late by within 72 hours: 60% penalty
- Late by within 96 hours: 80% penalty
- Late by over 96 hours: no credit
- If submission time is in doubt due to weekend/holidays (normally between Friday 4pm and Monday 4pm), the time calculation is taken in the favor of the student.

### Honor code

- By taking a course offered by JI, you are expected to abide by the JI Honor Code.
- Link: <u>http://umji.sjtu.edu.cn/academics/academic-integrity/honor-code/</u>
- Any suspected violation of the honor code will be reported to the Honor Council.
  - Past examples
- Discussing with classmates on homework problems is allowed, but having someone else's homework solution or any solution manual available when completing one's own homework is regarded as an Honor Code violation. That means it is prohibited to reference current or past classmates' solutions or online solution manuals. It is also prohibited to share your written solution to your classmates, including posting it to a public Internet site or transferring it electronically or in a printed form.

### About the instructor

- ▶ First name: Yongxing 泳星
- ▶ Last name: Shen 沈
- Email: yongxing.shen@sjtu.edu.cn
- Phone: 3420 7218
- Office: Room 212, JI Building
- Please call him: Prof. Shen (following the norm in China...)
- Degrees: Tsinghua (BEng), Stanford (MS, PhD)
- Homepage: <u>umji.sjtu.edu.cn/~yxshen</u>
- Main research field: computational fracture mechanics
- Other courses taught at JI:
  - Vk250: Principles of Engineering Materials
  - Vm211: Introduction to Solid Mechanics
  - Vm305: Introduction to Finite Elements in Mechanical Engineering
  - Vm505: Finite Element Methods
  - Vm511: Foundation of Solid Mechanics
- Office hours: TBD with Doodle. From the 2<sup>nd</sup> week of the semester

# About the teaching assistants

- ▶ Xiahan Li 李夏涵
  - Email: <u>lixiahan@sjtu.edu.cn</u>
  - Office hours: TBA
- Zeyu Xiong 熊泽宇
  - Email: <u>xiongzeyu1688@sjtu.edu.cn</u>
  - Office hours: TBA
- Note: The office hours will be announced via Canvas.

### Labs

- Lab 1: Friday, June 2, at class hour
  Lab 2: Friday, June 30, at class hour
- Location: Yu Liming Computer Room (3<sup>rd</sup> floor of JI Building)

### **Questions?**

- Office hours: To be decided with the help of a Doodle survey
- Recitation class: TBA