课程大纲
COURSE SYLLABUS

1.	课程代码/名称 **Course Code/Title**	**微型机器人 Microrobotics**
2.	课程性质 **Compulsory/Elective**	专业课
3.	课程学分/学时 **Course Credit/Hours**	48/3
4.	授课语言 **Teaching Language**	英文授课 English
5.	授课教师 **Instructor(s)**	郑裕基 U Kei Cheang
6.	是否面向本科生开放 **Open to undergraduates or not**	是 Yes
7.	先修要求 **Pre-requisites**	研究生： 无 本科生：ME307 控制工程基础或者 ME307-16 控制工程基础 Fundamentals of Control

8. 教学目标 Course Objectives

Acquire knowledge on the current progress in micro/nanorobots;

Understand theories relevant theories in areas such as scaling laws, low Reynolds number, and magnetism;

Study relevant techniques in micro/nanofabrication, fluid dynamics, imaging, tracking, control, etc.;

Investigate design criteria for micro/nanorobots.

9. 教学方法 Teaching Methods

Lectures with PowerPoint.

10. 教学内容 Course Contents

Section 1	Introduction: Lecture will include an introduction of the history of this field of research. The lecture will introduce the motivation of microrobotics and the ongoing developments in this field. Lecture also will introduce an overview of the essential technologies used in this field, such as microfabrication techniques, control systems, and imaging capability, and their limitations. Research of the instructor: Lecture will discuss the microrobotics research lead by the instructor, including the particle based microrobots and other key projects.
Section 2	Fluids Mechanics: Lecture will be a refresher on basic fluid mechanic concepts which will serve as foundation for microscale fluid mechanics Scaling Laws from macro to micro/nano: Lecture will include the principles behind scaling mobile robots from macroscale to microscale.
Section 3	Low Reynolds number Hydrodynamics: This topic will be closely connected to the previous topic, but with more specificity towards the principle of low Reynolds number. Lecture will include stokes flow, scallop theorem, nonreciprocal motion, etc.
Section 4	Microscale Mechanics: This topic will cover the relative importance of force at the

	microscale. Lecture will include various surface forces such as force that lead to adhesion and friction. Specific microfluidic phenomena will also be discussed, such as Brownian motion, viscous drag, Stoke's law, etc. Diffusivity: Lecture will introduce the concept of diffusivity which is a very important phenomenon to micro/nanoscale robots. Diffusion is a source of environmental disturbance that can significantly influence the swimming motion and trajectories of micro/nanorobots. Lecture will cover theoretical calculation of diffusion related parameters as well as experimental techniques to measure diffusion.
Section 5	Bio-inspired and inorganic micro/nanorobots case studies: Lecture will discuss the use of bio-inspired engineering based on the swimming mechanisms of microorganisms. Lectures will also explore the fabrication and actuation techniques of microrobots aimed towards biomimicry. Biological micro/nanorobots case studies: Lecture will discuss the microrobots that combine microbiology with engineered system. This will include the methods to culture microorganisms, to harness their propulsive power, to obtain bionanomaterial, and to exploit external stimuli for control. Case studies will include the flagellar nanoswimmers, bacteria-power microrobots, Tetrahymena microrobots, magnetotactic bacteria, etc.
Section 6	Engineering design of swimming mechanism: Lecture will discuss the use of engineered nonreciprocal swimming mechanisms that are effective at low Reynolds number. Lectures will introduce biologically inspired locomotion, theoretical locomotion such as the "Taylor sheet" and "Pushmepullyou" swimmers, and practical locomotion. Introduction to existing micro/nanorobots (Part 1): After gaining a foundation into the fundamental knowledge in microrobotics from the previous weeks, this week's lecture will dive deeper into the design, fabrication, control of micro/nanorobots currently in development. The lecture focus will be on helical chiral swimmers
Section 7	Introduction to existing micro/nanorobots (Part 2): After gaining a foundation into the fundamental knowledge in microrobotics from the previous weeks, this week's lecture will dive deeper into the design, fabrication, control, applications aspects of micro/nanorobots currently in development. This lecture will focus on flexible body swimmers, chemical swimmers, and surface microrobots.
Section 8	Applications examples: To facilitate the course project, the instructor will spend time at the beginning of lecture to introduce examples of possible applications for micro/nanorobotics. This will give the students an idea on what type of applications that can choose to address in their projects. Microfabrication Techniques: Lecture will explore microfabrication technologies that were used for existing microrobots and related engineered systems. This will include a various of techniques such as photolithograph, soft lithography, etching, thin film deposition, etc.
Section 9	Nanofabrication Techniques: Lecture will explore nanofabrication technologies that were used for existing micro/nanorobots and related engineered systems. This will include a various of techniques such as direct laser writing, templated directed electrodeposition, self-scrolling, shadow-growth, underpotential deposition, etc.
Section 10	Control methods: Lecture will cover the control systems used for various types of microrobots. The lecture will focus mostly on the development and functions of magnetic controllers, including hardware and software. Imaging and Tracking: Lecture will cover the imagining and tracking techniques used in microrobotic control systems. Due to the size of the microrobots, microscopes must be used for visualization. For data analysis and control, vision based tracking must also be employed. Lessons will introduce the use of MATLAB to develop tracking algorithms.
Section 11	Project Proposal Presentation: Students are expected to have chosen a topic for the course project and have done basic research. Students will give a 15-minute

		presentation on their plans for completing the project. A midterm report is also required.
	Section 12	Magnetism force and torque: Most micro/nanorobots are controlled using magnetic fields; therefore, this week’s lecture will introduce relevant concepts in magnetism. Lecture will cover the use of applied magnetic force and torque to actuate micro/nanorobots. Magnetic field generation: Lecture will include the practical application of electromagnetic coils to generate magnetic fields for controlling microrobots. Students will learn how to design electromagnetic coil systems with precise magnetic field generation. Concepts such as Helmholtz coils and Maxwell coils will be introduced. The contents of this week’s lecture will be driven by the theoretical concepts from the previous week’s topic.
	Section 13	Feedback and Multiple Robot Control: Lecture will cover strategies for controlling one or more microrobots. For more than one robots, it is an ongoing problem in microrobotics due to the fact that a global signal is often used to control microrobots; therefore, it is not possible to give individual inputs to individual robot. However, researcher have come up with ways to overcome this problem.
	Section 14	Particle Image Velocimetry (PIV): Lecture will cover Microscale Particle Image Velocimetry (μPIV) to study the hydrodynamics of swimming microrobots at low Reynolds number. If time permits, lecture will also cover the use of Finite Element Analysis (FEA) to study the flow fields of microrobots.
	Section 15	Applications: Lecture will cover in-depth case studies of the current state and future prospect of applications demonstrated by micro/nanorobotics such as transportation, tissue incision, retinal veins puncture, cell scaffolding, drug delivery, etc. Non-Newtonian Mechanics: Lecture will cover non-Newtonian fluid mechanics. Due to the non-linearity of non-Newtonian mechanics, the Purcell theorem no long holds. Thus, it is not valid to only consider the microscale mechanics discussed in previous lecture.
	Section 16	Final Project Presentations: Students are expected to work in teams to design of a viable microrobot that incorporate the knowledge gained throughout the course. Students will be required to submit a final report and give a 15-minute final presentation during the last week of class.

11. 课程考核 Course Assessment

Attendance		10 %
Homework		30 %
Design Project		60 %
Midterm presentation	15 %	
Midterm report	15 %	
Final presentation	15 %	
Final report	15 %	
Total		100 %

12. 教材及其它参考资料 Textbook and Supplementary Readings

Textbook (Suggested, not required): Metin Sitti, Mobile Microrobotics

Textbook (Suggested, not required): M.J. Kim, A.A. Julius, and U K. Cheang, Microbiorobotics Biologically Inspired Microscale Robotic Systems, 2nd edition

Textbook (Suggested, not required): M.J. Kim, A.A. Julius, and E.B. Steager, Microbiorobotics Biologically Inspired Microscale Robotic Systems, 1st edition

	Textbook (Suggested, not required): K. Breuer, Microscale Diagnostic Techniques Assortment of journal and conference papers