课程详述

COURSE SPECIFICATION

以下课程信息可能根据实际授课需要或在课程检讨之后产生变动。如对课程有任何疑问，请联系授课教师。

The course information as follows may be subject to change, either during the session because of unforeseen circumstances, or following review of the course at the end of the session. Queries about the course should be directed to the course instructor.

1.	**课程名称 Course Title**	**微型机器人 Microrobotics**
2.	**授课院系** **Originating Department**	机械与能源工程系 Department of Mechanical and Energy Engineering
3.	**课程编号** **Course Code**	ME334
4.	**课程学分 Credit Value**	3
5.	**课程类别** **Course Type**	专业选修课 Major Elective Courses
6.	**授课学期** **Semester**	春季学期
7.	**授课语言** **Teaching Language**	英文授课 English
8.	**授课教师、所属学系、联系方式（如属团队授课，请列明其他授课教师）** **Instructor(s), Affiliation& Contact** **（For team teaching, please list all instructors）**	郑裕基 机械与能源工程系 zhengyj@sustc.edu.cn U Kei Cheang Department of Mechanical and Energy Engineering
9.	**实验员/助教、所属学系、联系方式** **Tutor/TA(s), Contact**	待公布 To be announced
10.	**选课人数限额(可不填)** **Maximum Enrolment （Optional）**	

11. 授课方式 Delivery Method

学时数 Credit Hours

讲授 Lectures	**习题/辅导/讨论 Tutorials**	**实验/实习 Lab/Practical**	**其它(请具体注明) Other（Please specify）**	**总学时 Total**
48				48

12.	先修课程、其它学习要求 **Pre-requisites or Other Academic Requirements**	ME307 控制工程基础 Fundamentals of Control Engineering
13.	后续课程、其它学习规划 **Courses for which this course is a pre-requisite**	无
14.	其它要求修读本课程的学系 **Cross-listing Dept.**	无

教学大纲及教学日历 SYLLABUS

15. 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.

16. 预达学习成果 **Learning Outcomes**

ABET Criteria 3 Outcomes
0 = No content, 1 = Some content, 2 = Significant content

Outcomes a -k	Content	Explanation	Evidence
a. An ability to apply knowledge of mathematics, science and engineering	2	This course will require the students to develop a general understanding of technologies involved in microrobotics. The student will learn how to apply their knowledge in micro- and nanofabrication, fluids, controls, as well as other relevant disciplines.	Lecture, Homework, Project
b. An ability to design and conduct experiments as well as to analyze and interpret data	1	Assignments and course project will require students to design systems and analyze and interpret data.	Homework, Project
c. An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	1	Assignments will require considerations for societal or industrial needs.	Homework, Project
d. An ability to function on multidisciplinary teams	1	The course project will require students to work together on a multidisciplinary topic.	Design Project
e. An ability to identify, formulate and solve engineering problems	2	The homework and project will require students to identify, formulate and solve engineering problems.	Homework, Design project
f. An understanding of professional and ethical responsibility	1	This will be emphasized as part of the engineer's overall responsibility.	Classroom discussion
g. An ability to communicate effectively	2	Written report and presentation for the project demonstrate students' ability to communicate effectively.	Final report for Project
h. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	1	The impact of micro- and nanorobotics on a global, economic, environmental, and societal context will be covered.	Classroom discussion, Project
i. A recognition of the need for and an ability to engage in lifelong learning	1	The emerging field of science and engineering will be engaged in lifelong learning.	Classroom discussion
j. A knowledge of contemporary issues	1	The difficulties in developing fabrication techniques at the micro and nanoscale will be discussed.	Classroom discussion, Lecture
k. An ability to use the techniques, skills and modern engineering tools necessary for engineering practice	1	Lectures and assignments will cover theoretical use of advanced techniques in micro- and nanotechnology.	Lecture, Homework, Project

17. 课程内容及教学日历 （如授课语言以英文为主，则课程内容介绍可以用英文；如团队教学或模块教学，教学日历须注明主讲人）
Course Contents (in Parts/Chapters/Sections/Weeks. Please notify name of instructor for course section(s), if this is a team teaching or module course.)

Section	Description	Hours
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.	3
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.	3
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.	3
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.	3
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.	3
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	3
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.	3
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.	3
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.	3
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	3

	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.	
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.	3
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.	3
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.	3
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.	3
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.	3
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.	3

18. 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

课程评估 ASSESSMENT

19.

评估形式 **Type of Assessment**	评估时间 **Time**	占考试总成绩百分比 **% of final score**	违纪处罚 **Penalty**	备注 **Notes**
出勤 **Attendance**	无	10%	Adhere to school policy on academic integrity	无
课堂表现 **Class Performance**	无	无	无	无
小测验 **Quiz**	无	无	无	无
课程项目 **Projects**	10 hours	45%	Adhere to school policy on academic integrity	无
平时作业	3 hours per week	30%	Adhere to	无

Assignments			school policy on academic integrity	
期中考试 **Mid-Term Test**	无	无	无	无
期末考试 **Final Exam**	无	无	无	无
期末报告 **Final Presentation**	4 hours	15%	Adhere to school policy on academic integrity	无
其它（可根据需要改写以上评估方式） **Others (The above may be modified as necessary)**	无	无	无	无

20. 记分方式 **GRADING SYSTEM**

√A. 十三级等级制 **Letter Grading**

☐ B. 二级记分制（通过/不通过） **Pass/Fail Grading**

课程审批 REVIEW AND APPROVAL

21. 本课程设置已经过以下责任人/委员会审议通过

This Course has been approved by the following person or committee of authority

机械与能源工程系教学委员会