

## 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.	<b>课程名称 Course Title</b>	机器人驱动系统 Robotic Actuation System
2.	<b>授课院系 Originating Department</b>	机械与能源工程系
3.	<b>课程编号 Course Code</b>	ME322
4.	<b>课程学分 Credit Value</b>	3
5.	<b>课程类别 Course Type</b>	专业核心课 Major Core Courses
6.	<b>授课学期 Semester</b>	秋季 Fall
7.	<b>授课语言 Teaching Language</b>	中英双语 English & Chinese
8.	<b>授课教师、所属学系、联系方式 Instructor(s), Affiliation &amp; Contact</b> (For team teaching, please list all instructors)	王宏强 WANG Hongqiang
9.	<b>实验员/助教、所属学系、联系方式 Tutor/TA(s), Contact</b>	待公布 To be announced
10.	<b>选课人数限额(可不填) Maximum Enrolment (Optional)</b>	

11. 授课方式 Delivery Method	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
	32		32		64
学时数 Credit Hours					
12. 先修课程、其它学习要求 Pre-requisites or Other Academic Requirements	高等数学 A 下 MA102B				
13. 后续课程、其它学习规划 Courses for which this course is a pre-requisite					
14. 其它要求修读本课程的学系 Cross-listing Dept.					

### 教学大纲及教学日历 SYLLABUS

#### 15. 教学目标 Course Objectives

机器人驱动系统是机械与能源工程系本科生的专业核心课，其他专业具备相应基础知识且对课程具有兴趣的学生可选修本课程，本课程的先修课程为高等数学 A 下。

本课程的主要任务是从机器人驱动系统的角度讲授各类机器人驱动器的基本结构、工作原理和工作特性，如传统的电磁电机、静电驱动器、形状记忆聚合物、气动驱动器、液压驱动器、IPMC 驱动器、压电驱动器、介电弹性体驱动器；同时结合了机器人驱动系统中至关重要的传感、控制等技术，为学生讲述一个完整的机器人驱动系统是如何组成、感知和控制；此外，本课程还设立了与理论课教学进度一致的实验教学培养环节，以结合实际培养学生的工程能力、帮助学生理解驱动器的原理，包括拆解电机、驱动电机、数据分析、多自由度驱动系统的设计搭建与驱动等；同时实验教学培养环节在期末时设立了开放性的项目，鼓励学生结合课程内容进行创新，培养学生的文献检索能力、创新实践能力、科研表达的能力。经过本课程一个学期的学习后，期望能够为学生建立对各类机器人驱动系统的基本认知，不仅在以后从事机器人、机电系统设计等方向的工程能力有所帮助，还能够为有志于机器人驱动相关科研研究的学生奠定基础知识，尤其是提供了足够广度的新型机器人驱动系统的前沿知识。

Robotic Actuation is a major core course for undergraduates of The Department of Mechanical and Energy Engineering. Students with relevant basic knowledge and interest in this course could take this course. The prerequisite of this course is Calculus II A (MA102B).

ME322 consist of 3 credits, includes, lecture: 2 credits, 2 hours per week, laboratory course: 1 credit, 2 hours per week. Prerequisites: Calculus II A (MA102B). This course explains the primary structure, principle, and characteristics of actuators based on different principles, such as electromagnetic motors, electrostatic actuators, shape memory actuators, and pneumatic actuators, and the controlling methods and sensory techniques. Experimental sessions will follow the schedule with the theory courses to cultivate the engineering ability of students and help them understand the actuators the course better. The experiments include disassembling motors, controlling actuators and motors, designing and constructing a multi-DOF actuation system, etc.

#### 16. 预达学习成果 Learning Outcomes

学习本课程后，应达到如下学习成果：

1. 了解各类驱动器的基本结构
2. 了解各类驱动器的基本工作原理和工作特性
3. 掌握各类电磁电机运动的基本方程式及其推导
4. 掌握各类驱动器的分析计算方法
5. 掌握机器人驱动系统中传感与控制的原理

6. 驱动器选型的能力
7. 科研表达能力与科研创新能力
8. 资料检索与收集能力
9. 项目沟通与合作能力

Students are expected to achieve the following goals after finishing this course:

1. Understand the basic structure of different kinds of actuators
2. Understand the basic principle and working characteristics of kinds of actuators
3. Master the basic equations and derivation of kinds of electromagnetic motors
4. Master the analytical calculation methods of kinds of actuators
5. Master the principle of sensing and controlling for robotic actuation system
6. Ability of selecting the appropriate actuators
7. Ability of scientific expression and innovation
8. Ability of data retrieval and collection
9. Ability of communication and coordination

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.)**

课程内容/ Course content	教学要求/ Teaching requirement	学时分配
绪论/ Introduction <ul style="list-style-type: none"> <li>• 驱动器定义</li> <li>• 机器人与机器人系统定义</li> <li>• 机器人与驱动系统的组成</li> <li>• 各类驱动器系统的发展历程</li> <li>• 各类驱动器系统的应用场景</li> <li>• 本课程的性质、任务和主要内容</li> <li>• Definition of actuators</li> <li>• Definition of robot and it's system</li> <li>• The components of robots and the actuation system</li> <li>• Development of different types of actuators</li> <li>• Application scenario of different types of actuators</li> <li>• Syllabus, including course type, assignment and main contents of the course</li> </ul>	了解机器人的发展史、组成结构以及各类型驱动器的历史背景、应用场景，了解本课程的学习目标与主要内容。 Understand the historical background and application scenarios of different types of actuators, and the learning objectives and main contents of this course.	2
电磁电机绪论/ Introduction of electromagnetic motor <ul style="list-style-type: none"> <li>• 电磁电机定义</li> <li>• 电磁电机的分类和功能</li> <li>• 电磁电机中的电磁场基本理论</li> <li>• Definition of motor</li> <li>• Classification and function of motor</li> <li>• Basic electromagnetic relations in motor</li> </ul>	了解电磁电机的发展史、组成结构以及各类型电磁电机的驱动方式、功能的不同，对电磁电机的驱动原理与构造有基本的认识。 Understand the development history of electromagnetic motor, composition structure and the different driving mode and function of various types of electromagnetic motor, have a	4

	basic understanding of the driving principle and structure of electromagnetic motor.	
直流无刷电机/ Brushless DC motor <ul style="list-style-type: none"> <li>• 直流无刷电机的基本工作原理</li> <li>• 直流无刷电机的基本结构</li> <li>• 直流无刷电机的主要参数</li> <li>• 直流无刷电机的主要特性</li> <li>• Basic working principle of brushless DC motor</li> <li>• Basic structure of brushless DC motor</li> <li>• Main parameters of brushless DC motor</li> <li>• Key features of brushless DC motors</li> </ul>	了解直流无刷电机的基本工作原理、基本结构、主要参数和主要特性，结合其在机器人驱动系统中的实际应用进行认识。 Understand the basic working principle, basic structure, main parameters, and main characteristics of brushless DC motor, combined with its practical application in robotic actuation system.	2
直流有刷电机/ Brush DC motor <ul style="list-style-type: none"> <li>• 直流有刷电机的基本工作原理</li> <li>• 直流有刷电机的基本结构</li> <li>• 直流有刷电机的主要参数</li> <li>• 直流有刷电机的主要特性</li> <li>• 直流有刷电机的控制与输出</li> <li>• 直流有刷电机的应用</li> <li>• Basic working principle of DC brush motor</li> <li>• Basic structure of DC brush motor</li> <li>• Main parameters of DC brush motor</li> <li>• Key features of DC brush motors</li> <li>• DC brushless motor control and output</li> <li>• DC brush motor applications</li> </ul>	了解直流有刷电机的基本工作原理、基本结构、主要参数和主要特性，结合其在机器人驱动系统中的实际应用进行认识，并重点对其驱动方式进行学习。 Understand the basic working principle, basic structure, main parameters, and main characteristics of brush DC motor, combined with its practical application in robotic actuation system, then focus on the study of its driving mode.	6
期中复习与测试 Mid-term review and test	考核学生对知识的掌握情况，并帮助梳理教学内容，体现前半学期存在的教学问题，以便后续能更好的因材施教，并鼓励学生学习，确保学生能够更好的掌握知识。 Help students sort out the teaching knowledge and assess their mastery, reflect the teaching problems existing in the first half of the semester, to better teach students according to their aptitude in the follow-up, also encourage students to learn, ensure that students could absorb knowledge well.	2
<ul style="list-style-type: none"> <li>• 综述机器人的传感器分类</li> <li>• 主要传感原理与方法</li> <li>• Review of the categories of robotics sensing</li> <li>• Principle and mechanism of primary sensing methods</li> <li>• The key parameters of sensors</li> </ul>	了解机器人综述机器人的传感器分类、理解主要传感原理与方法、传感器的关键参数 Understand the categories of the robotics sensing, the principle and mechanism of primary sensing methods	2

<ul style="list-style-type: none"> <li>• 传感器的静态特性</li> <li>• 传感器的动态特性</li> <li>• Static characteristics of the sensors</li> <li>• dynamic characteristics of the sensors</li> </ul>	<p>了解机器人传感的关键参数与信号处理方法</p> <p>Understand the Static characteristics of the sensors and dynamic characteristics of the sensors</p>	2
<ul style="list-style-type: none"> <li>• 静电电机的基本工作原理</li> <li>• 静电电机的关键设计参数</li> <li>• 静电电机的制造方法</li> <li>• 静电电机的应用场景</li> <li>• Principles of electrostatic actuators</li> <li>• Key design parameters of electrostatic actuators</li> <li>• Fabrication of electrostatic actuators</li> <li>• Application scenario of electrostatic actuators</li> </ul>	<p>了解静电电机的基本工作原理及关键设计参数，熟悉静电电机的制造方法及应用场景</p> <p>Understand the basic principles of electrostatic actuators and its key design parameters, familiar with the fabrication and application of electrostatic actuators</p>	2
<ul style="list-style-type: none"> <li>• 形状记忆合金的分类</li> <li>• 形状记忆合金的材料及工作原理</li> <li>• 形状记忆聚合物的材料及工作原理</li> <li>• 形状记忆合金、形状记忆聚合物的应用场景</li> <li>• Classification of shape memory alloys (SMA)</li> <li>• Principles and materials of shape memory alloys</li> <li>• Principles and materials of shape memory polymers (SMP)</li> <li>• Application scenario of SMA and SMP</li> </ul>	<p>了解形状记忆合金的分类、形状记忆合金的材料、形状记忆聚合物的材料，熟悉形状记忆合金、形状记忆聚合物的工作原理及应用场景</p> <p>Understand the classification and materials of SMA and SMP, familiar with the principles and application scenario of SMA and SMP</p>	2
<ul style="list-style-type: none"> <li>• 液压、气压驱动的基本原理</li> <li>• 液体、气体动力学的基本概念</li> <li>• 液体、气体软体驱动的方式和方法</li> <li>• 液压、气压驱动的常用元件</li> <li>• 液压、气压泵的工作原理</li> <li>• 液压、气压驱动的适用场景</li> <li>• Basic principles of hydraulic and pneumatic actuators</li> <li>• Basic concepts of hydrodynamics and gas kinetics</li> <li>• Common components for hydraulic and pneumatic driving</li> <li>• Principles of hydraulic pump and air pump</li> <li>• Applications of hydraulic and pneumatic driving</li> </ul>	<p>了解液压、气压驱动的基本原理及适用场景，熟悉液压、气压泵的工作原理，掌握液体、气体动力学的基本概念、掌握液压、气压驱动的常用元件选用方法</p> <p>Understand the basic principles and applications of hydraulic and pneumatic driving, familiar with the principles of hydraulic pump and air pump, master the basic concepts of hydrodynamics and gas kinetics, and selection methods for common components of hydraulic and pneumatic driving</p>	2
<ul style="list-style-type: none"> <li>• 压电效应</li> <li>• 常见压电材料</li> <li>• 压电驱动器的关键参数</li> <li>• 压电驱动器的应用场景</li> <li>• Piezoelectric effect</li> <li>• Common piezoelectric materials</li> <li>• Key design parameters of piezoelectric actuators</li> <li>• Application scenario of piezoelectric actuators</li> </ul>	<p>了解常见压电材料的种类、压电驱动器的关键参数，熟悉压电效应的内容及压电驱动器的应用场景</p> <p>Learn about the common piezoelectric materials, the key design parameters of piezoelectric actuators, familiar with the piezoelectric effect and application scenario of piezoelectric actuators</p>	2

<ul style="list-style-type: none"> <li>• 离子交换聚合金属材料驱动器的工作原理</li> <li>• 离子交换聚合金属材料驱动器的应用场景</li> <li>• 离子交换聚合金属材料驱动器的制造方法</li> <li>• 介电弹性体驱动器的工作原理</li> <li>• 介电弹性体驱动器的应用场景</li> <li>• 介电弹性体驱动器的制造方法</li> <li>• Principles of ion-exchange polymer metal composite (IPMC)</li> <li>• Application scenario of IPMC</li> <li>• Fabrication of IPMC</li> <li>• Principle of dielectric elastomer actuators (DEA)</li> <li>• Application scenario of DEA</li> <li>• Fabrication of DEA</li> </ul>	<p>了解离子交换聚合金属材料驱动器的制造方法，熟悉离子交换聚合金属材料驱动器的工作原理和应用场景</p> <p>了解介电弹性体驱动器的制造方法，熟悉介电弹性体驱动器的工作原理和应用场景</p> <p>Understand the fabrication of IPMC, familiar with the principles and application of IPMC</p> <p>Understand the fabrication of DEA, familiar with the principles and application scenario of DEA</p>	2
<p>期末复习与测试 Final review and test</p>	<p>对机器人驱动系统有个整体的了解，巩固知识，并通过问题帮助学生融合知识，提出自己的解决思路</p> <p>Have an overall understanding of robot drive system, consolidate knowledge, and help students to integrate knowledge through questions, put forward their own solutions</p>	2
<p>实验教学</p>		
<ul style="list-style-type: none"> <li>• 常见电机功能介绍与机器人研究院实验室参观</li> <li>• Introduction of common actuators and visit the laboratories of robotics research institute</li> </ul>	<p>了解机器人实际应用中电机的种类和特性</p> <p>Understand the types and characteristics of actuators in the practical application of robots.</p>	2
<ul style="list-style-type: none"> <li>• 常见电机拆装实验</li> <li>• Common actuators disassembly experiment</li> </ul>	<p>了解常见电机各部分的工作原理</p> <p>Understand the working principle of common actuators' parts.</p>	2
<ul style="list-style-type: none"> <li>• Arduino 舵机控制实验</li> <li>• Arduino steering engine control experiment</li> </ul>	<p>学习使用舵机的基本原理，并使用 PWM 对舵机进行控制</p> <p>Learn the basic principle of using steering gear, and use PWM to control steering engine.</p>	2
<ul style="list-style-type: none"> <li>• 闭环步进电机驱动控制实验</li> <li>• Closed-loop stepper motor drive control experiment</li> </ul>	<p>学习闭环步进电机的具体结构与基本控制原理，并实现闭环步进电机的实时控制</p> <p>Learn the structure and basic control principle of closed-loop stepping motor, and realize the real-time control of closed-loop stepping motor</p>	4
<ul style="list-style-type: none"> <li>• 直流无刷电机的调试与控制</li> <li>• Debug and control brushless DC motor</li> </ul>	<p>学习直流无刷电机的驱动板与调试软件</p> <p>Learn the drive board and debugging software of brushless DC motor</p>	2

<ul style="list-style-type: none"> <li>• 三自由度移动平台综合实验</li> <li>• Comprehensive experiment of 3-DOF mobile platform</li> </ul>	学习三自由度移动平台的硬件结构和安装，学习控制软件和指令，实现各类运动控制 Learn the hardware structure and installation of 3-DOF mobile platform, learn control software and instructions, and realize all kinds of motion control	4
<ul style="list-style-type: none"> <li>• 软体驱动器制备实验</li> <li>• Soft actuators preparation experiment</li> </ul>	学习气动和线驱动软体机器人驱动系统的搭建 Learn pneumatic and wire-driven soft robotic actuation system construction	2
<ul style="list-style-type: none"> <li>• 软体驱动器测试实验</li> <li>• Soft actuators measurement experiment</li> </ul>	学习软体机器人驱动器的驱动原理与力学特性 Learning the driving principle and mechanical characteristics of soft robot actuators	2
<ul style="list-style-type: none"> <li>• 静电电机驱动实验</li> <li>• Experiments on electrostatic actuators</li> </ul>	学习静电电机驱动系统的搭建 Learn the construction of electrostatic motor drive system	2
<ul style="list-style-type: none"> <li>• 形状记忆合金与 IPMC 驱动器实验</li> <li>• Experiments on shape memory alloy and IPMC actuators</li> </ul>	学习形状记忆合金和 IPMC 驱动器系统的搭建 Learn shape memory alloy and IPMC driver system construction	2
<ul style="list-style-type: none"> <li>• 适配柔性夹爪的三轴抓取平台实验</li> <li>• Three-axis grasping platform experiment with flexible gripper</li> </ul>	学习结合柔性夹爪与三自由度移动平台，并实现抓取 Learn the combination of flexible gripper and 3-DOF mobile platform, and realize grasping	4
<ul style="list-style-type: none"> <li>• 最终汇报</li> <li>• Final Presentation</li> </ul>	适配柔性夹爪的三轴抓取平台实验汇报 Final presentation for three-axis grasping platform with flexible gripper	2

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

<p>《电机学（第七版）》 电子工业出版社 Stephen D. Umans 著，刘新正、苏少平、高琳译</p> <p>《电机学》 西安交通大学出版社 阎治安,苏少平,崔新艺著</p>
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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		10	每缺席一次扣除 2%，缺席三次以上扣除全部 10%	
课程项目 Projects		40		
平时作业 Assignments		30		

期末报告  
Final  
Presentation

	20		
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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

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