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**	高等机构学及其应用 Mechanisms and Applications
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**	ME315
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**	秋季 Fall
7.	**授课语言** **Teaching Language**	英文 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）**	戴建生 机械系与能源工程系 daijs@sustech.edu.cn
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	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
	学时数 Credit Hours	48		0	0	48

12.	先修课程、其它学习要求 Pre-requisites or Other Academic Requirements	线性代数 A（MA107A）、高等数学（下）A（MA102B） Linear algebra (MA107A), Calculus IIA(MA102B)
13.	后续课程、其它学习规划 Courses for which this course is a pre-requisite	无 NA
14.	其它要求修读本课程的学系 Cross-listing Dept.	无 NA

教学大纲及教学日历 SYLLABUS

15. 教学目标 Course Objectives

This lecture will introduce preliminary mathematics and fundamental of mechanisms to enable students to understand the basic concepts, such as scalars and vectors, projective geometry and homogenous coordinates, degrees of freedom, Grashof condition, Grübler-Kutzbach Criterion, etc. The lecture will teach the basic skills such as the associate graphs, the kinematics sketch, and simplified diagrams to analyze the structure of a machine. This will then be further carried out by going through the position analysis and velocity analysis. The orientation through matrix presentation and analysis is to be taught in detail and this will be associated to mechanism analysis and synthesis.

The lecture will instruct students on how to design mechanisms by using topological methods, topological synthesis or type synthesis methods, it will also teach students to analyze classical mechanisms such as planar mechanisms, spatial mechanisms, Bennett linkage, Myard linkage, Bricard linkage, and novel mechanisms such as metamorphic spatial linkages and oriblocks.

16. 预达学习成果 Learning Outcomes

The students will learn the design and analysis methods of mechanisms and robotics, enabling them to have strong competitiveness in employment or further study.

First, students will use Denavit-Hartenberg homogeneous transformation matrices and loop-closure equations in the position analysis of mechanisms, apply the Grübler-Kutzbach criterion and constraint-screw system decomposition theorem to calculate degrees of freedom and analyze the mobility of mechanisms and robots. They will also complete stiffness and dynamics analysis of mechanisms and robots.

Then, students will grasp the concepts of classical linkages like Bennett linkage, Myard linkage, Bricard linkage, and Schatz linkage. They can design and analyze these types of mechanisms. Students can also design modern mechanisms proposed in recent years, such as metamorphic spatial linkage, thick-panel origamis and oriblocks.

Finally, students know how to construct antennas by assembling spatial linkages like Bennett linkage, Myard linkage and Bricard linkage, they can also design metamaterials and metamorphic crawling robots.

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.)

Part I.	**Preliminary Mathematics (week 1~week 2)**
1	**Vector Algebra**
1.1.	Scalars and vectors
1.2.	Multiplication by a scalar
1.3.	Basis vectors and components
1.4.	Magnitude of a vector
1.5.	Multiplication of vectors
1.6.	Equations of lines and planes
2	**Coordinate of Points, Vectors and Lines**
2.1.	Position and direction vectors
2.2.	Vector equation of lines
2.3.	Projective geometry and homogeneous coordinates
2.4.	Line as joint of two points and the Plücker coordinates
2.5.	Line as intersection of two planes
2.6.	Intrinsic properties of axis and ray coordinates
Part II.	**Fundamental of Mechanisms (week 3~week 5)**
1	**Concept of Mechanisms**
1.1.	Degrees of freedom
1.2.	Planar linkages
1.3.	Grashof condition
1.4.	Grashof-type rotatability criteria for higher-order linkages
1.5.	Spherical linkages
1.6.	Spatial linkages
1.7.	Over-constrained mechanisms
2	**Graphic Representation of Mechanisms**
2.1.	Schematic representation of links and joints

2.2.	Vectorization of mechanisms
2.3.	Associated graph of mechanisms
2.4.	Topological synthesis methods
2.5.	Topological analysis methods
2.6.	Gran analysis of mechanisms
3	**Matrix Theory**
3.1.	The transpose of a matrix
3.2.	The complex and Hermitian conjugates of a matrix
3.3.	The trace of a matrix
3.4.	The determinant of a matrix
3.5.	The inverse of a matrix
3.6.	The rank of a matrix
3.7.	Special types of a square matrix
3.8.	Change of basis and similarity transformations
3.9.	Adjacency matrix of mechanisms
4	**Screw Theory**
4.1.	The screw
4.2.	Screw operation
4.3.	Dual form of screws and screw operation
4.4.	Twists and Mozzi's instantaneous screw axis
4.5.	Wrenches and Poinsot's central axis theorem
4.6.	Analogy between instantaneous kinematics and statics
4.7.	Reciprocity
4.8.	Reference screws
4.9.	Lie algebra and its representations
4.10.	Lie operation, Lie bracket, and the theorem of equivalence
Part III.	**Basic Analysis of Mechanisms (week 6~week 10)**
1	**Synthesis Methods of Mechanisms**

1.1.	Type synthesis
1.2.	Dimensional synthesis
1.3.	Graphical synthesis
1.4.	The overlay method
1.5.	Analytical synthesis
1.6.	Three-precision-point synthesis
1.7.	Order synthesis
2	**Position Analysis of Mechanisms**
2.1.	Link parameters and link coordinate systems
2.2.	Denavit-Hartenberg homogeneous transformation matrices
2.3.	Loop-closure equations
2.4.	Other coordinate systems
2.5.	Denavit-Hartenberg method
2.6.	Method of successive screw displacements
2.7.	Solution of displacement equations
3	**Kinematic Analysis of Mechanisms**
3.1.	Grübler-Kutzbach criterion
3.2.	Constraint-screw system decomposition theorem
3.3.	Mobility analysis
3.4.	Velocity analysis
3.5.	Vector-loop method
4	**Jacobian Analysis of Mechanisms**
4.1.	Differential kinematics of a rigid body
4.2.	Differential kinematic of serial mechanisms
4.3.	Screw coordinates and screw systems
4.4.	Mechanism Jacobian matrix
4.5.	Conventional Jacobin
4.6.	Screw-based Jacobian

4.7.	Transformation of screw coordinates
4.8.	Relationship between the two methods
4.9.	Condition number
4.10.	Singularity analysis
5	**Statics and Stiffness Analysis of Mechanisms**
5.1.	Statics of serial mechanisms
5.2.	Transformation of forces and moments
5.3.	Stiffness analysis of serial mechanisms
5.4.	Statics of parallel mechanisms
5.5.	Stiffness analysis of parallel mechanism
6	**Dynamics of Mechanisms**
6.1.	Mass properties
6.2.	Momentum
6.3.	Transformation of inertia matrix
6.4.	Kinetic energy
6.5.	Newton-Euler laws
6.6.	Recursive Newton-Euler formulation
6.7.	Lagrangian formulation
6.8.	Inertia effects of the rotors
6.9.	End-Effector space dynamical equation
6.10.	Principle of virtual work
Part IV.	**Classical Mechanisms (week 11~week 12)**
1	**4-bar Spatial Linkage**
1.1.	Bennett linkages
1.2.	Mobility analysis
2	**5-bar Spatial Linkage**
2.1.	Myard linkages
2.2.	Mobility analysis

3	**6-bar Spatial Linkage**
3.1.	Plane-symmetric Bricard linkage
3.2.	Trihedral Bricard linkage
3.3.	Goldberg 6R linkage
3.4.	Schatz linkage
3.5.	Mobility analysis
Part V.	**Modern Mechanisms (week 13~week 14)**
1	**Metamorphic Linkages**
1.1.	Bennett linkage inspired 6R metamorphic linkage
1.2.	Line-symmetric Goldberg 6R metamorphic linkage
1.3.	spherical-planar and Bennett-spherical 6R metamorphic linkages
1.4.	Schatz-inspired metamorphic linkage
1.5.	Symmetric Waldron-Bricard Metamorphic linkage
1.6.	8-kaleidocyle-inspired 8R metamorphic linkage
1.7.	Plane-symmetric single-loop 8R metamorphic linkage
2	**Thick-Panel Origamis**
2.1.	Tapered panels technique
2.2.	Offset panel technique
2.3.	Hinge shift technique
2.4.	Doubled hinge technique
2.5.	Rolling contacts technique
2.6.	Membrane technique
3	**Oriblocks**
3.1.	Pyramidal oriblocks
3.2.	Prismatic oriblocks
3.3.	Cylindrical oriblocks
3.4.	Conical oriblocks
Part VI.	**Applications of Mechanisms and Robots (week 15~week 16)**

1	**Deployable Antennas**
1.1.	Assembly of Bennett linkages
1.2.	Assembly of Myard linkages
1.3.	Assembly of Bricard linkages
2	**Metamaterials**
2.1.	Metamaterials based on thick-panel origamis
2.2.	Metamaterials based on cylindrical oriblocks
2.3.	Metamaterials based on conical oriblocks
3	**Metamorphic Crawling Robots**
3.1.	Design of metamorphic crawling robots
3.2.	Analysis of metamorphic crawling robots

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

1. 戴建生，《旋量代数与李群李代数》出版于高等教育出版社“现代数学基础”丛书，2020 年第二版/37 万字/375 页

2. 戴建生，《机构学与机器人学的几何基础与旋量代数》出版于高等教育出版社“机器人科学与技术”丛书， 2018 年再次印刷/58 万字/488 页

3. 戴建生 等，《可重构机构与可重机器人——分岔演变的运动学分析、综合及其控制》出版于高等教育出版社“机器人科学与技术”丛书，国家科学技术学术著作出版基金资助出版，2021 年/64 万字/516 页

4. C. Qiu, J.S. Dai, 2020. 《Analysis and Synthesis of Compliant Parallel Mechanisms—Screw Theory Approach》, Springer, London. ISBN: 978-3-030-48312-8

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	每月一次 once a month	5%	无	无
课堂表现 Class Performance	每月一次 once a month	5%	无	无
小测验 Quiz	无	0	无	无
课程项目 Projects	无	0	无	无
平时作业 Assignments	期中和期末各一次 Mid-term and end-of-term	90%	无	无

期中考试 Mid-Term Test	无	0	无	无
期末考试 Final Exam	无	0	无	无
期末报告 Final Presentation	无	0	无	无
其它（可根据需要改写以上评估方式） Others (The above may be modified as necessary)				

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