Course guide
820018 - STM - Mechanical Systems

Last modified: 31/01/2025

Unit in charge:	Barcelona East School of Engineering
Teaching unit:	712 - EM - Department of Mechanical Engineering. 737 - RMEE - Department of Strength of Materials and Structural Engineering.
Degree:	BACHELOR'S DEGREE IN BIOMEDICAL ENGINEERING (Syllabus 2009). (Compulsory subject). BACHELOR'S DEGREE IN CHEMICAL ENGINEERING (Syllabus 2009). (Compulsory subject). BACHELOR'S DEGREE IN ELECTRICAL ENGINEERING (Syllabus 2009). (Compulsory subject). BACHELOR'S DEGREE IN ENERGY ENGINEERING (Syllabus 2009). (Compulsory subject). BACHELOR'S DEGREE IN INDUSTRIAL ELECTRONICS AND AUTOMATIC CONTROL ENGINEERING (Syllabus 2009). (Compulsory subject). BACHELOR'S DEGREE IN MECHANICAL ENGINEERING (Syllabus 2009). (Compulsory subject). BACHELOR'S DEGREE IN MATERIALS ENGINEERING (Syllabus 2010). (Compulsory subject).

Academic year: 2024 **ECTS Credits:** 6.0 **Languages:** Catalan, Spanish

LECTURER

Coordinating lecturer: MARIA DE LA VEGA PEREZ GRACIA

Others:
Primer quadrimestre:
JAVIER ALONSO CARRASCO - Grup: T12, Grup: T13, Grup: T23
RODRIGO ESTEBAN ALVA BAÑUELOS - Grup: M51, Grup: M52, Grup: M53, Grup: M54
MANUEL ALEJANDRO CAICEDO SILVA - Grup: M33
WALTER CRUPANO - Grup: T11, Grup: T12, Grup: T13
BRUNO MARTINEZ ALEMANY - Grup: M41, Grup: M42, Grup: M43, Grup: M44
EVA MARTÍNEZ GONZÁLEZ - Grup: M11, Grup: M12, Grup: M21, Grup: M22
RAUL MENDUIÑA MONTERO - Grup: M31, Grup: M32
MARIA DE LA VEGA PEREZ GRACIA - Grup: M31, Grup: M32, Grup: M33, Grup: M34
FRANCISCO QUINTILLA BLANCO - Grup: M13, Grup: M14, Grup: T11, Grup: T21, Grup: T22, Grup: T23
DÍDAC SÁNCHEZ COLL - Grup: T21, Grup: T22
GIL SERRANCOLÍ MASFERRER - Grup: M11, Grup: M12, Grup: M13, Grup: M14, Grup: M21, Grup: M22, Grup: M23, Grup: M24
MOHAMMAD TALHA SHARIF RAFIQUE - Grup: M51, Grup: M52, Grup: M53, Grup: M54
JUAN VELAZQUEZ AMEIJIDE - Grup: M23, Grup: M24, Grup: M33, Grup: M34, Grup: M41, Grup: M42, Grup: M43, Grup: M44

PRIOR SKILLS

Previous knowledge on: vector mechanics applied to point masses, vector product, product mix, calculation with matrices, trigonometry, definite integrals, double integrals, triple integrals.

Previous skills: working group (level I).

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
1. Understand the theoretical principles of machines and mechanisms.
2. Understand and apply the principles of the strength of materials.

Transversal:
5. SELF-DIRECTED LEARNING - Level 2: Completing set tasks based on the guidelines set by lecturers. Devoting the time needed to complete each task, including personal contributions and expanding on the recommended information sources.
3. TEAMWORK - Level 2. Contributing to the consolidation of a team by planning targets and working efficiently to favor communication, task assignment and cohesion.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION - Level 1. Planning oral communication, answering questions properly and writing straightforward texts that are spelt correctly and are grammatically coherent.
4. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.

TEACHING METHODOLOGY

The subject combines the expository methodology (approximately 40%) with individual work (more or less 40%) and with practices (20% of the time). In the practice activity, group work is developed and the autonomous learning process is carried out by taking advantage of the resources offered to the students.

This subject has scheduled reevaluation tests, regulated by the center's regulations.

LEARNING OBJECTIVES OF THE SUBJECT

General objectives: introduce students to the basic concepts of systems in equilibrium, the geometric properties of sections and the moment of inertia of masses, developing their ability to solve static equilibrium problems related to machines, mechanisms and structures, calculation of the geometric properties of sections and moments of inertia of masses.

General (transversal) skills: the subject is designed to encourage the practice of teamwork skills, promoting the practice of skills necessary for this type of work.

At the end of the course, the student must be able to:
- Work with systems of forces in balance in 2D and 3D.
- Obtain systems of equivalent forces and couples.
- Identify isostatically determined structures, knowing how to calculate the reactions in their joints and supports.
- Determine all the forces that act on each piece or element of a structure, machine or mechanism under conditions of static equilibrium.
- Calculate axial stresses in longitudinal axial elements.
- Calculate centers of gravity of surfaces and volumes in two and three dimensions.
- Apply knowledge of centers of gravity to solve problems of beams with distributed loads.
- Apply knowledge of centers of gravity to calculate the external surface and volume of pieces of revolution.
- Understand and explain what are the moments of inertia, the polar moment of inertia, the products of inertia, the principal axes of inertia and the principal moments of inertia.
- Calculate the moments and products of inertia of surfaces and masses, with respect to any axis or point.
- determine the main axes of inertia centered at a given point, and the associated moments of inertia.
- Use Mohr's circle.
- Solve balance problems that involve friction forces.
- Apply the conditions of static equilibrium to systems and particular cases in which friction forces occur, analyzing the equilibrium conditions of the system.
- Develop skills and techniques that facilitate group work.

STUDY LOAD

Type	Hours	Percentage
Hours small group	15,0	10.00
Hours large group	45,0	30.00
Self study	90,0	60.00

Total learning time: 150 h

CONTENTS

Topic 1. EQUILIBRIUM OF THE RIGID SOLID

Description:
1.1. Review of concurrent forces at a point and balance of a point through resolution of balance problems.
1.2. Review of:
a) Moment of a system of forces with respect to a point.
b) Moment of a system of forces with respect to an axis.
1.3. Review of torque.
1.4. Equivalent force systems:
a) Definition of equivalent systems
b) Force-couple systems
c) Simplest possible equivalent system in the case of coplanar forces
d) Simplest equivalent system possible in the case of parallel forces
e) General case: torsional moment and torque wrench
1.5. Equilibrium of a rigid solid:
a) Concept of balance in two dimensions and in three dimensions
b) Static equilibrium conditions
c) Particular case of a solid subjected to forces at two points
d) Particular case of a solid subjected to forces at three points
1.6. Reactions at supports in two dimensions
1.7. Reactions in supports in three dimensions
1.8. Resolution of reaction problems in supports in two dimensions and in three dimensions.
1.9. Difference between hyperstatic systems and isostatic systems.

Specific objectives:
At the end of the topic, the student should be able to solve any type of statically determined problem when it can be simplified to the study of one point. She will be able to calculate the moment of a system of forces with respect to a point and with respect to an axis, both in two and three dimensions, working with vectors and modules and differentiating the results in each case. She will be able to identify the pairs of forces and will know how to associate them with the equivalent moment vector. She must be able to solve balance problems in which pairs of forces, moments and point forces appear. She will know how to calculate equivalent force-couple systems in two dimensions and in three dimensions, and will also be able to make their graphical representation. She will know how to obtain the simplest possible equivalent system of a system of forces when these are parallel to each other or coplanar. You will also be able to calculate the torque and torque wrench when you must obtain the simplest possible equivalent system of any system of forces in three dimensions (which do not meet the conditions of parallelism or being contained in the same plane). You will be able to draw the free solid diagram of a two-dimensional or three-dimensional body, being able to identify the equilibrium conditions in each case and resolving the forces that are unknown as long as they are isostatic structures, which you will be able to clearly identify and differentiate from a hyperstatic structure. .

Related activities:
Theoretical explanations and resolution of individual and group problems in the classroom and outside of it. Laboratory practices 1, 2 and 5.

Full-or-part-time: 16h
Theory classes: 6h
Laboratory classes: 4h
Self study : 6h

Topic 2. ANALYSIS OF STRUCTURES IN BALANCE

Description:
2.1. Definition and differences of types of structures:
a) Articulated structures or armor
b) Frameworks or frameworks
c) Machines and mechanisms
2.2. Resolution of articulated structures in two dimensions using the knot method.
23. Special configurations of forces and unloaded bars.
2.4. Resolution of articulated structures in 2D using the method of sections:
a) Conditions to apply the method
b) Sections that cut more than three bars
c) Problem solving
2.5. Resolution of articulated structures in 2D using jointly the method of nodes and that of sections
2.6. Resolution of simple articulated structures in 3D using the knot method.
2.8. Resolution of frameworks.
2.9. Machine resolution

Specific objectives:
At the end of the topic, the student should be able to calculate the force on each element of an articulated structure, using the method of knots, the Ritter method or both together. He must be able to distinguish unloaded elements and draw correct free solid diagrams, whether of an element, a set of elements or the entire structure. He must also be able to resolve frameworks, machines and mechanisms, being able to differentiate elements that are axial from those that are not. He will also know how to work with joints between three or more elements, joints to which a point force is applied and which join two or more elements, and with joints between a support and two or more pieces. He must know how to solve simple three-dimensional articulated structures using the knot method. He must also be able to calculate the stress in an axial element and the minimum section that the axial piece must have when the maximum stress it can withstand is known.

Related activities:
Theoretical explanations in the classroom. Resolution of individual and group problems in the classroom and also outside of school hours.

Full-or-part-time: 15h
Theory classes: 3h
Laboratory classes: 2h
Self study : 10h

Chapter 3. CENTROIDS, CENTERS OF MASS AND CENTERS OF GRAVITY

Description:
3.1. Definitions, difference between centroid, center of mass and center of gravity
3.2. Centroids of lines, areas and simple volumes
3.3. Centroids of lines, areas and composite volumes
3.4. Application 1 of centroids: point force systems equivalent to distributed forces on beams
3.5. Application 2 of centroids: Pappus-Guldinus theorems
3.6. Centers of mass and centers of gravity of simple bodies in two and three dimensions
3.7. Centers of mass and centers of gravity of composite bodies in two and three dimensions

Specific objectives:
At the end of the topic, the student should be able to define and illustrate with examples the distributions of linear, surface and volume forces. He must know the differences between the concept of centroid, center of mass and center of gravity, identifying the situations in which they coincide. You must be able to obtain the expressions for the coordinates of the centroids of lines, areas and volumes, and know how to use them to determine the centroid of a line, an area or a simple volume by integration. He must also be able to obtain and understand expressions for lines, areas and composite volumes, being able to calculate the centroid of any line, area or composite volume. She must know and recognize the first order moments for lines, for areas and for volumes. He should be able to use symmetries in problem solving. You must be able to present calculations and results in an organized manner using tables. It must be able, for any load distribution on a beam, to obtain the equivalent point force and its point of application on the beam, being able to use this data in the subsequent calculation of the structure. You must also be able to calculate the center of mass and the center of gravity of bodies in two dimensions and in three dimensions, both simple and compound. He must be able to correctly use the Pappus-Guldinus theorems to obtain the volume and external surface of bodies of revolution.

Related activities:
Theoretical explanations in the classroom. Resolution of individual and group problems in the classroom and also outside of school hours. Laboratory practice 3

Full-or-part-time: 19h
Theory classes: 6h
Laboratory classes: 1h
Self study : 12h

Chapter 4. MOMENTS OF INERTIA OF SECTIONS

Description:
5.1. Definitions: moment of inertia for areas, moment of inertia for mass, polar moment of inertia for areas, radius of gyration, product of inertia. Applications and comparison between moment of inertia for areas and moment of inertia for mass.
5.2. Moments of inertia and products of inertia for simple areas.
5.3. Parallel axes theorem.
5.4. Moments of inertia and products of inertia for composite areas.
5.5. Moments yand products of inertia with respect to rotated axes.
5.6. Principal axes of inertia and principal moments of inertia. Tensor of inertia.
5.7. Cercle of Mohr.

Specific objectives:
At the end of this chapter, the student will be able to:

1) known the definitions of moment of inertia for areas, indicating the mathematical formula and explaining examples.
2) known the units.
3) calculate the moments of inertia with respect the cartesian axes for a simple area by integration.
4) calculate the polar moment of inertia by integration for a simple area; the radius of gyration with respect the cartesian axes and the polar radius of gyration.
5) calculate the product of inertia for a simple area by integration.
6) define the conditions for the applications of the parallel axes theorem, explaining them.
7) Solve problems about moments of inertia for sections in 2D, using if necessary the parallel axes theorem one ore more than one times, and the known expressions for the moentos of inertia for simple areas.
8) Apply the parallel axes theorem when the known moment of inertia is referred to the centroidal axis or to the non-centroidal axis.
9) Determine the moment of inertia for composite areas.
10) Relate the moments of inertia with respect rotated axes.
11) Define the principal axes and principal moments of inertia.
12) Calculate the principal axes and the principal moments of inertia.
13) Draw the circle of Mohr in the different cases.

Related activities:
Theoretical explanations at class. Resolution of individual and grupal problems at class and at home.

Full-or-part-time: 29h
Theory classes: 9h
Self study : 20h

Chapter 5. MOMENTS OF INERTIA MASS

Description:
6.1. Definition of moment of inertia of a mass
6.2. Moments of inertia for thin plates
6.3. Parallel axes theorem
6.4. Momenos of inertia and products of inertia for simple mass.
6.5. Momenos of inertia and products of inertia for composite mass.

Specific objectives:
At the end of this chapter, the student will be able to:

1) Define and illustrate with examples the moment of inertia for masses, indicating its mathematical expression.
2) Known the units and the differences with the moment of inertia for areas
3) Calculate the moment of inertia for simple bodies by using the moments of inertia for thin plates and the parallel axes theorem
4) Use the symmetries in the calculation of the moments and products of inertia of simple bodies
5) Use the known expression of moments of inertia for simple bodies and the parallel axes theorem to calculate the moment of inertia of composite bodies

Related activities:
Theoretical explanations at class. Resolution of individual and grupal problems at class and at home.

Full-or-part-time: 16h
Theory classes: 6h
Self study : 10h

Topic 6. DRY FRICTION

Description:
Dry friction and several applications focused to statics and constant motion:

7.1. Dry friction of Coulomb friction
7.2. Friction coefficients and friction angles
7.3. Inclined plane and problems about dry friction
7.4. Applications with friction (wedges, belts,...)

Specific objectives:
At the end of this part, the student will be able to:

1) Define dry friction
2) Solve simple problems of equilibrium with friction forces
3) Solve problems of structures or machines in which friction forces are applied
4) Determine the conditions of static equilibrium in the cases of problems with friction forces
5) Solve determined applications with friction forces (wedges, screws...)

Related activities:
Theoretical explanations at class. Resolution of individual and grupal problems at class and at home. Lab practice 4

Full-or-part-time: 20h
Theory classes: 9h
Laboratory classes: 1h
Self study : 10h

GRADING SYSTEM

Evaluation of the subject: there will be a first term exam (40% of the grade), a final exam that will include the entire subject syllabus (45% of the grade), laboratory practice reports (5% of the grade) and practice control (10% of the grade). The final exam covers the entire subject matter and allows the student to retake the partial exam.

In the event of failing the part assessed through the partial exam and final exam, the student may take a re-evaluation exam when the requirements set by the center are met and at all times following the regulations in force at the time of taking the test. Therefore, those students who meet the requirements set by the EEBE in the Evaluation and Permanence Regulations (https://eebe.upc.edu/ca/estudis/normatives-academiques/documents/eebe_normativa_avalua_perman_2023_2024_2024_acord_rovje0_202.

EXAMINATION RULES.

The first term exam, the final exam, and the revaluation exam will be held on the dates indicated by the center in each course

Laboratory practices: they cannot be recovered. In the case of not being able to attend a session, you must notify and change the practice date with a colleague from another group or attend the practice with another group of the subject in which there is a free place. There is no practice recovery session. The reports are delivered at the end of the session in the format indicated for each course, and it is only possible to deliver them if you have attended the laboratory session.

Practice control: it will be a test type and can be in person or online. It will be held on the day and time indicated by the subject's teaching team, which will be the same for all groups.

BIBLIOGRAPHY

Basic:
- Bedford, A.; Fowler, W. Mecánica para ingeniería, vol. 1, Estática [on line]. 5a ed. México: Pearson Educación, cop. 2008 [Consultation: 29/04/2020]. Available on: http://www.ingebook.com/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=1285. ISBN 9786074428766.
- Beer, F. P. [et al.]. Mecánica vectorial para ingenieros : estática [on line]. 10a ed. México [etc.]: McGraw-Hill, cop. 2017 [Consultation: 12/06/2020]. Available on: http://www.ingebook.com/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=8077. ISBN 9781456269173.
- Riley, W. F.; Sturges, L. D. Ingeniería mecánica : estática. Barcelona [etc.]: Reverté, 1995-1996. ISBN 842914255X.

Complementary:
- Nelson, E. W.; Best, C. L.; McLean, W. G. Mecánica vectorial : estática y dinámica. 5ª ed. Madrid [etc.]: McGraw-Hill, cop. 2004. ISBN 8448129504.
- Beer, F. P.; Johnston, E. R.; Eisenberg, E. R. Mecánica vectorial para ingenieros : dinámica [on line]. 10a ed. México [etc.]: McGraw-Hill, cop. 2013 [Consultation: 12/06/2020]. Available on: http://www.ingebook.com/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=4261. ISBN 9781456218324.
- Spiegel, M. R.; Abellanas, L.; Liu, J. Fórmulas y tablas de matemática aplicada [on line]. 4ª ed. Madrid [etc.]: Mc Graw-Hill, cop. 2014 [Consultation: 12/06/2020]. Available on: http://www.ingebook.com/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=5688. ISBN 9781456239596.
- Gordon, J. E. Estructuras : o por qué las cosas no se caen. Madrid: Calamar, cop. 2004. ISBN 8496235068.
- Walker, J. "The mechanics of rock climbing, or surviving the ultimate physics exam". Scientific American. Vol. 260, núm. 6 (1989), p. 118-121.
- Gere, J. M.; Timoshenko, S.; Bugeda, G. Resistencia de materiales. 5ª ed. España [etc.]: International Thomson Editores, cop. 2002. ISBN 8497320654.

RESOURCES

Audiovisual material:
- Videos docents. Resource
- Videos docents. Resource