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820018 - STM - Mechanical Systems

Coordinating unit: 295 - EEBE - Barcelona East School of Engineering

Teaching unit: 737 - RMEE - Department of Strength of Materials and Structural Engineering

Academic year: 2019

Degree: BACHELOR'S DEGREE IN ELECTRICAL ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN MECHANICAL ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN BIOMEDICAL ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN ENERGY ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN CHEMICAL ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN INDUSTRIAL ELECTRONICS AND AUTOMATIC CONTROL ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN MATERIALS ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN BIOMEDICAL ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN ELECTRICAL ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN ENERGY ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN INDUSTRIAL ELECTRONICS AND AUTOMATIC CONTROL ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN MECHANICAL ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN CHEMICAL ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)

ECTS credits: 6 Teaching languages: Catalan, Spanish

Teaching staff

Coordinator: MARIA DE LA VEGA PEREZ GRACIA

Others: Primer quadrimestre:
DAVID ARCOS GUTIÉRREZ - M11, M12, M13, M14
EDUARD CALDUCH PROS - M11, M12, M33, M34
SERGIO MORALES PLANAS - M31, M32
MARIA DE LA VEGA PEREZ GRACIA - M31, M32, M33, M34
FRANCISCO QUINTILLA BLANCO - T11, T12, T13, T14
ANTONIO JOSÉ SÁNCHEZ EGEA - M21, M22, M23, M24
VIVIANA ALEJANDRA SOSSA ARANCIBIA - M23, T13, T14, T23
JUAN VELAZQUEZ AMEIJIDE - T21, T22, T23

Opening hours

Timetable: To be decided each course

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).

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Requirements

Physics I
Mathematics II

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.
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.
3. TEAMWORK - Level 2. Contributing to the consolidation of a team by planning targets and working efficiently to favor communication, task assignment and cohesion.
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 methodology is based on theoretical exposition (40%), individual work (20%), work in small groups (cooperative, collaborative or otherwise) by 25%, and practices (15%), approximate values. The autonomous learning process is developed also using the digital campus Athena, where resources are included as well as self-assessment questionnaires, specifications about the workgroups , information about an article in English that must be analyzed, and debate topics that will be discussed on-line during the semester.

The competence "workgorups" is developed during the laboratory practices, by using the autoevaluation and the peer evaluation. The basis for working with these activities are provided to the students in the digital campus Atenea. Students have also in this virtual campus templates to assess the group performance, including the detection of tasks and works to be improved, the actions to obtain best results and the control of these results.

There are re-evaluation exams, based in the school normative and regulations.

Learning objectives of the subject

Specific skills. General objectives: The subject introduce the student in the basics of static, developing their ability to solve problems of static equilibrium. Also it introduce the basical concepts about strength of materials. The student will define and illustrate (with examples) the distributions of linear, surface or volume forces.

General skills (cross-curricular skills). General objectives: the subject is designed to favor the practice of the team work skill, promoting habilities needed to work properly with a team or group-work.

After completing this course, students will be able to:
1) work with systems of forces in 2D and 3D.
2) Get equivalent systems of forces and torques.
3) Identify isoestàtic structures , knowing to calculate the reactions in their joints and supports.
4) Compute centers of gravity of surfaces and volumes 2 and 3 dimensions.
5) Apply knowledge of centers of gravity to solve problems of beams with distributed loads.

6) Apply knowledge of centers of gravity to solve problems of flat surfaces and curved submerged.
7) Apply knowledge of centers of gravity to calculate the external surface and volume in the particular case of revolution bodies.
8) Understand and explain the moments of inertia, polar moment of inertia, products of inertia, principal axes of inertia, principal moments of inertia.
9) Calculate masses and surfaces inertia moments and products with respect to any axis or point.
10) Determine the principal axes of inertia centered on a particular point, and the associated moments of inertia.
11) Apply the Mohr circle.
12) Solve equilibrium problems with friction forces.
13) Analyse the static equilibrium in particular cases with friction forces, defining the possible conditions of equilibrium in each case.
14) Develop and implement technical skills to facilitate teamwork.
15) Organize a team with a small clarametn particular purpose.
16) Evaluate the product of the work, and the work of their peers.
17) Analyze the group behavior and evaluate possible improvements.

Study load

Total learning time: 150h	Hours large group:	45h	30.00%
	Hours medium group:	0h	0.00%
	Hours small group:	15h	10.00%
	Guided activities:	0h	0.00%
	Self study:	90h	60.00%

Content

Item 1. Vector mechanics	Learning time: 16h Theory classes: 6h Laboratory classes: 4h Self study : 6h

Description:
1.1. Momentum of a 3D forces system referred to a point.
1.2. Momentum of a 3D forces system referred to an axis.
1.3. Torque and force-couple systems equivalent.
1.4. Simplest equivalent force system in the case of parallel forces systems in 3D.
1.5. Simplest equivalent force system in the case of coplanar forces in 3D.
1.6. Simplest equivalent force system in the case general forces in 3D: torsional moment.

Related activities:
Theoretical explanations in the classroom. Resolution of individual and group problems in the classroom. Response to a self-learning test in the virtual campus Athena. Debate on-line on various aspects related to the topic. Laboratory practices.

Specific objectives:
At the end of the topic, the student should be able to solve any static determined problem, when it can be simplified to the study of a point. The student will be able to calculate the momentum caused by any forces system referred to a point or to an axis. The student should be able to identify the pairs of forces and to associate the equivalent momentum vector, to calculate in 2D and 3D equivalent force-couple systems, obtaining also its graphical representation, to obtain the simplest system
equivalent of a parallel or coplanar forces system. The student will also be able to calculate the torsional moment as the simplest equivalent system of a general 3D forces system (not parallel or coplanar forces).

Item 2. Solid rigid equilibrium	Learning time: 15h Theory classes: 3h Laboratory classes: 2h Self study : 10h

Description:
2.1. Solid rigid, deformable solid, and concept of balance.
2.2. Balance in two dimensions.
2.3. Balance in three dimensions.
2.4. Solid statically indeterminate.
2.5. Special cases of solids subjected to two and three forces.

Related activities:
Theoretical explanations in the classroom. Resolution of individual and group problems in the classroom. Response to a self-learning test in the virtual campus Athena. Debate on-line on various aspects related to the topic. Using the tools learned to develop a part of groupwork. Reading, undestand and analyze a popular scientific or technical paper.

Specific objectives:
At the end of the item, the student should be able to properly define a rigid body and a deformable solid, an isoestatic structur, and an hiperstatic (inderterminate) structure. The student should be able to define general conditions of static equilibrium in 2D and 3D, and the equations to represent these conditions. The student must draw correctly a free-body diagrams, considering the reactions at the supports. The student will be able to calculate the reactions in the supports of an isostatic structure, both two and three dimensions.

Item 3. Analysis of structures in equilibrium	Learning time: 30h Theory classes: 10h Laboratory classes: 0h Self study : 20h

Description:
4.1. introduction to the structures.
4.2. Articulated structures in two dimensions: method of joints and method of sections or Ritter.
4.3. Articulated structures in three dimensions.
4.4. Frameworks.
4.5. Machines.

Related activities:
Theoretical explanations in the classroom. Resolution of individual and group problems in the classroom. Response to a self-learning test in the virtual campus Athena. Debate on-line on various aspects related to the topic. Using the tools learned to solve the problems proposed at laboratory and at class.

Specific objectives:
After completing the topic, the student must identify and separate the internal and external forces for any statically supported structure; define axial elements and identify the base line of forces on rigid bodies in equilibrium when subjected to two forces; differentiate and identify articulated structures, frames and machines; indicate
correctly tension or compression in an balance element subjeted to two forces; properly make the analysis of statically supported structures by using the method of joints; properly make the analysis of statically supported structures by using the method of sections or Ritter; properly make the analysis of articulated structures statically supported selecting the most appropriate method: joints and sections method separately or joint both methods; recognize the limitations of the two methods (knots and sections). The student will be also able to analize static and simple (not necessary to consider one or more joints as separate elemetns) frameworks; to analyze a statically supported framework when one or more joints must be considered as separate elements. The student will be able to correctly draw free-body diagrams of a machines, taking special care in the direction and sign of external forces applied on the machine; to analyze a symmetric machine (e.g., scissors) using statics; to analyze using statics machines with no symmetry.

Item 4. Centers of gravity	Learning time: 19h Theory classes: 6h Laboratory classes: 1h Self study : 12h

Description:
3.1. Definitions.
3.2. Simple areas and lines centroids.
3.3. Complex areas and lines centroids.
3.4. Centroids applications: distributed forces in a beam.
3.5. Centers of mass of simple bodies in 3D.
3.6. Volume centers of mass of compounds bodies in 3D.
3.7. Theorems of Pappus-Guldinus.

Related activities:
Theoretical explanations in the classroom. Resolution of individual and group problems in the classroom and at home. Response to a self-learning test in the virtual campus Athena. Debate on-line on various aspects related to the topic. Using the tools learned to solve problems proposed in laboratory and in class.

Specific objectives:
At the end of the topic, the student should be able to define and illustrate with examples the linear, surface and volume force distributions; explain what is the center of gravity of a flat surface and a line presenting constant density and section; express and define the first-order moments of areas and lines; consider symmetry axes, and symmetry points, in the calculatio of the center of gravity of 2D sections; calculate the center of gravity of a single area and a single line by integration, define the center of gravity of a composed area or line using the known centers of gravity of simple lines and areas (management of tables); calculate the center gravity of 2D and 3D sections or lines, using tables, presenting calculations and results in an organized manner, using tables; determine the total equivalent charge and the application point on non-deformable beamswhere two-dimensional linear distributions are applied, obtaining both the module and the point of application of the equivalent point charge; identify areas and volumes of revolution from sections; demonstrate and explain the Pappus-Guldinus theorems; calculate the external surface and the volume of any piece of revolution using the Pappus-Guldinus theorems. The student will be also able, for any homogeneous density mass, to determine the expressions that allow to obtain the coordinates of center of gravity position by integration; to calculate the center of gravity of a mass with constant density by integration in the case of bodies with one, two or no plans of symmetry; to calculate the center of gravity of a variable density mass by integration in the case of bodies with one, two or no planes of symmetry; to determine the position of revolution volumes center of gravity; to calculate the center of gravity position of composed volumes presenting homogeneous or non-homogeneous densities, using tables.

Item 5. MOMENTS OF INERTIA OF SECTIONS	Learning time: 29h Theory classes: 9h Self study : 20h

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.

Related activities:

Theoretical explanations at class. Resolution of individual and grupal problems at class and at home. Self-learning tests in the Virtual Campus Atenea. Discussion about different aspects related with the topics.

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.

Item 6. MOMENTS OF INERTIA MASS	Learning time: 16h Theory classes: 6h Self study : 10h

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

Related activities:
Theoretical explanations at class. Resolution of individual and grupal problems at class and at home. Self-learning tests in the Virtual Campus Atenea. Discussion about different aspects related with the topics.

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

Topic 7. FRICTION	Learning time: 20h Theory classes: 9h Laboratory classes: 1h Self study : 10h

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, flat-head screws,...)

Related activities:
Theoretical explanations at class. Resolution of individual and grupal problems at class and at home. Self-learning tests in the Virtual Campus Atenea. Discussion about different aspects related with the topics.

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...)

Qualification system

The students will be able to access the re-assessment test that meets the requirements set by the EEBE in its Assessment and Permanence Regulations (https://eebe.upc.edu/ca/estudis/normatives-academiques/documents/eebe-normativa-avaluacio-i-permanencia-18-19-aprovat-je-2018-06-13.pdf)

Regulations for carrying out activities

Tests called (2) -long time works- can't be repeated because the feedback is assured during the work development. This feedback should guide the student in the procedures, allowing to improve the final result. The deadline is the last day to deliver the final work. Works presented after deadline will not be accepted.
The tests called (1) -evidence in specific time-, must be done in punctual moments.
Documentation about the workgroup -handed by the virtual campus Atenea- includes the description about the form and the content of the final work document.

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Bibliography

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Complementary:

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Walker, J. "The mechanics of rock climbing, or surviving the ultimate physics exam". Scientific American. Vol. 260, núm. 6 (1989), p. 118-121.

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