Course guide
300206 - MEC - Mechanics

Last modified: 01/06/2023

Unit in charge: Castelldefels School of Telecommunications and Aerospace Engineering
Teaching unit: 748 - FIS - Department of Physics.

Degree: BACHELOR'S DEGREE IN AEROSPACE SYSTEMS ENGINEERING (Syllabus 2015). (Compulsory subject).

Academic year: 2023 **ECTS Credits:** 6.0 **Languages:** Catalan, Spanish, English

LECTURER

Coordinating lecturer: Definit a la infoweb de l'assignatura.

Others: Definit a la infoweb de l'assignatura.

PRIOR SKILLS

- Developed skills in basics of trigonometry, vector calculus, differential and integral calculus.
- Familiarity with the concepts of physical magnitude, units an unit conversion.
-Familiarity in the use of scientific notation.
-Familiarity with the concepts of force, work, energy, rigid solid and field.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE2. CE 2 AERO. Comprensión y dominio de los conceptos básicos sobre las leyes generales de la mecánica, termodinámica, campos y ondas y electromagnetismo y su aplicación para la resolución de problemas propios de la ingeniería. (CIN/308/2009, BOE 18.2.2009)
CE3. CE 3 AERO. Conocimientos básicos sobre el uso y programación de los ordenadores, sistemas operativos, bases de datos y programas informáticos con aplicación en ingeniería. (CIN/308/2009, BOE 18.2.2009)

Generical:
CG1. (ENG) CG1 - Capacidad para el diseño, desarrollo y gestión en el ámbito de la ingeniería aeronáutica que tengan por objeto, de acuerdo con los conocimientos adquiridos, los vehículos aeroespaciales, los sistemas de propulsión aeroespacial, los materiales aeroespaciales, las infraestructuras aeroportuarias, las infraestructuras de aeronavegación y cualquier sistema de gestión del espacio, del trafico y del transporte aéreo.
CG2. (ENG) CG2 - Planificación, redacción, dirección y gestión de proyectos, cálculo y fabricación en el ámbito de la ingeniería aeronáutica que tengan por objeto, de acuerdo con los conocimientos adquiridos, los vehículos aeroespaciales, los sistemas de propulsión aeroespacial, los materiales aeroespaciales, las infraestructuras aeroportuarias, las infraestructuras de aeronavegación y cualquier sistema de gestión del espacio, del trafico y del transporte aéreo.

Transversal:
CT6. SELF-DIRECTED LEARNING - Level 1. Completing set tasks within established deadlines. Working with recommended information sources according to the guidelines set by lecturers.
CT7. 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.
CT3. 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.
CT4. TEAMWORK - Level 1. Working in a team and making positive contributions once the aims and group and individual responsibilities have been defined. Reaching joint decisions on the strategy to be followed.
CT5. EFFECTIVE USE OF INFORMATI0N RESOURCES - Level 1. Identifying information needs. Using collections, premises and services that are available for designing and executing simple searches that are suited to the topic.

Basic:
CB1. (ENG) CB1 - Que los estudiantes hayan demostrado poseer y comprender conocimientos en un área de estudio que parte de la base de la
educación secundaria general, y se suele encontrar a un nivel que, si bien se apoya en libros de texto avanzados, incluye también algunos aspectos que implican conocimientos procedentes de la vanguardia de su campo de estudio
CB2. (ENG) CB2 - Que los estudiantes sepan aplicar sus conocimientos a su trabajo o vocación de una forma profesional y posean las competencias que suelen demostrarse por medio de la elaboración y defensa de argumentos y la resolución de problemas dentro de su área de estudio
CB3. (ENG) CB3 - Que los estudiantes tengan la capacidad de reunir e interpretar datos relevantes (normalmente dentro de su área de estudio)
para emitir juicios que incluyan una reflexión sobre temas relevantes de índole social, científica o ética
CB4. (ENG) CB4 - Que los estudiantes puedan transmitir información, ideas, problemas y soluciones a un público tanto especializado como no especializado
CB5. (ENG) CB5 - Que los estudiantes hayan desarrollado aquellas habilidades de aprendizaje necesarias para emprender estudios posteriores con un alto grado de autonomíA

TEACHING METHODOLOGY

Master classes are combined with applied lectures and the use of multimedia material. Master classes will mainly follow the talk-chalk method, so that the teacher may efficiently present the main concepts and physical laws. These will be later applied during homework and exercise sessions. Students' participation will be encouraged during lessons. Specific examples will be chosen according both to their pedadgogical value (in order to clarify as much as possible theoretical concepts) and to the specific degree this subject belongs to, in order to motivate students. Besides multimedia tools will be used whenever possible, in order to help visual understanding.

Oriented activities are aimed to facilitate students' participation, and let them develop, either individually or in groups, the work done during master classes. Profit from oriented activities is directly related to autonomous dedication time. Small group discussions will be favoured for the students to share the approach and results of exercises done as homework.

A computing project will be proposed, in order to help the development of transversal activities, and to deepen in the concepts of this subject. A computer code to be written in small groups, and the detailed analysis of results will be expected. Projects and a related test will be avaluated with 20% of the subjects total mark.

LEARNING OBJECTIVES OF THE SUBJECT

At the end of the term students must be able to:
- Solve basic Mechanical problems using Newton Laws and integration methods (for non-constant forces).
- Use conservation theorems (linear and angular momentum, energy).
- Identify different types of oscillators. Write and solve their equations of motion.
- Know the magnitudes of power, bandwidth, frequency of resonance, relaxation time and quality factor.
- Define the concepts of conservative force and central force. Identify and calculate basic orbital parameters. Define and calculate transfer orbits of different types.
- Define inertial and non-inertial frames of reference. Express and transform magnitudes between different frames and the intervening forces.
- Explain the concepts of tensor of inertia, Euler equations, Euler angles and Euler angle rates, both in classical and aeronautical notation. Explain cases of basic rotational dynamics.
- Be efficient both in oral and written communication in order to justify scientific reasoning with qualitative and quantitative arguments. Critically analyse reasoning, in order to detect and ultimately avoid errors.
- Efficiently find and use information in English, Spanish and Catalan.
- Build a code to solve problems in Mechanics through numerical integration.
- Work on a team project.

STUDY LOAD

Type	Hours	Percentage
Self study	84,0	56.00
Hours large group	42,0	28.00
Guided activities	24,0	16.00

Total learning time: 150 h

CONTENTS

Introduction to Classical Mechanics

Description:
- Introduction and basic concepts.
- Main principles in classical Mechanics. Conservation theorems: energy, linear and angular momenta.
- Applications: Newton laws with variable forces.

Related activities:
2 sessions in this block. Proposed activities:
- Session 1: discuss and correct exercises (conservation principles, time-dependent forces)
- Session 2: discuss and correct exercises (velocoty and position-dependent forces)

Full-or-part-time: 20h 30m
Theory classes: 5h 30m
Guided activities: 3h
Self study : 12h

(ENG) Títol contingut 2: Oscil·lacions

Description:
- Review Simple Harmonic Oscillations.
- Damped oscillations..
- Driven oscillations. Resonance.

Related activities:
3 sessions in this block. Proposed activities:
- Session 3: discuss and correct exercises (simple and damped oscillators; driven oscillators and resonance)
- Session 4: Test

Full-or-part-time: 21h
Theory classes: 7h
Guided activities: 3h
Self study : 11h

(ENG) Títol contingut 3: Forces centrals

Description:
- Plane kinematics
- 3-dimensional motion. Angular momentum
- Conservative forces and potential energy. Central forces.
- Motion under central forces inversely proportional to the square of the distance. Gravity. Orbital parameters. Kepler's laws.
- Ellipticcal, parabolic and hyperbolic orbits.
- Transfer orbits. Hohmann orbits.

Related activities:
2 sesions in this block. Proposed activities:
- Session 5: discuss and correct exercises (plane kinematics. Central forces)
- Session 6: discuss and correct exercises (orbital parameters and transfer orbits)

Full-or-part-time: 20h 30m
Theory classes: 5h 30m
Guided activities: 3h
Self study : 12h

(ENG) Títol contingut 4: Sistemes de Partícules

Description:
- Dynamics of systems of particles.
- Linear momentum and energy conservation for systems of particles.
- Centre of mass.
- Variable-mass problems. The rocket equation.

Related activities:
1 session in this block. Proposed activities:
- Session 7: discuss and correct exercises (conservation principles, centre of mass, rocket equation)

Full-or-part-time: 17h 30m
Theory classes: 5h
Guided activities: 1h 30m
Self study : 11h

(ENG) Títol contingut 6: Sistema de coordenades mòbils

Description:
- Mobile frames of reference. Axes translation.
- Rotating frames of reference.
- Centrifugal and Coriolis acceleration.

Related activities:
2 sections in this block. Proposed activities:
- Session 8: discuss and correct exercises (conservation principles, time-dependent forces)
- Session 9: discuss and correct exercises (velocoty and position-dependent forces)

Full-or-part-time: 20h 30m
Theory classes: 5h 30m
Guided activities: 3h
Self study : 12h

(ENG) Sòlid Rígid. Rotació entorn d'un eix fix i en torn a un eix variable.

Description:
- Dynamics of rigid solid
- Review rotation about a fixed axis.
- Angular momentum and tensor of inertia of a rigid solid.
- Kinetic energy of a rigid solid.
- Motion of rigid solid in space.
- Euler equations.
- Euler angles. Euler angle rates.

Related activities:
2 sesions in this block. Proposed activities:
- Session 10: discuss and correct exercises (review 1-dim rotation. Tensors of inertia.)
- Session 11: discuss and correct exercises (tensors of inertia and Euler equations. Euler angles and Euler angle rates).
Session 12: Test.

Full-or-part-time: 30h
Theory classes: 9h
Guided activities: 3h
Self study : 18h

ACTIVITIES

(ENG) TÍTOL ACTIVITAT 1: INTRODUCCIÓ A L'ASSIGNATURA

Description:
Introduction to Classical Mechanics. Exercises of variable forces.

Specific objectives:
Introduction to Classical Mechanics course. Consolidate concepts of basic Physics. Understandand solve problems involving variable forces.

Material:
Online version of exercise collection and solved examples.

Delivery:
Students will hand in proposed exercises during the session.

Full-or-part-time: 2h
Guided activities: 2h

(ENG) TÍTOL ACTIVITAT 2: FORCES DEPENENTS DE LA POSICIÓ, EL TEMPS I LA VELOCITAT

Full-or-part-time: 2h
Guided activities: 2h

VARIABLE FORCES II

Description:
Problems on variable forces will be solved and discussed.

Specific objectives:
Understand and solve variable forces exercises.

Material:
Online version of exercise collection and solved examples.

Delivery:
Students will hand in proposed exercises.

Full-or-part-time: 2h
Guided activities: 2h

OSCILLATIONS

Description:
Exercises on oscillators of different types will be solved and discussed.

Specific objectives:
Understand the physics of oscillations of different types. Analyse the dynamics of oscillations. Understand the concept of resonance and its relevance in practical situations.

Material:
Students will hand in proposed exercises.

Full-or-part-time: 2h
Guided activities: 2h

(ENG) TÍTOL ACTIVITAT 5: CONTROL DE PROBLEMES I

Description:
A test will be done

Specific objectives:
Let teachers and student grasp the information and understanding achieved by students.

Material:
Hardcopy of test

Delivery:
Students will present the solved test.

Full-or-part-time: 2h
Theory classes: 2h

(ENG) TÍTOL ACTIVITAT 6: FORCES CONSERVATIVES I CENTRALS. MOMENT ANGULAR

Description:
Exercises of this chapter will be solved and discussed.

Specific objectives:
Understand the concepts of conservative and central forces. Understand and use concepts of potential energy and angular momentum.

Material:
Online version of exercise collection.

Delivery:
Students will hand in proposed exercises.

Full-or-part-time: 2h
Guided activities: 2h

(ENG) TÍTOL ACTIVITAT 7: FORCES QUE DEPENEN DE R AL QUADRAT. ORBITES I LLEIS DE KEPLER

Description:
Exercises of this chapter will be solved and discussed.

Specific objectives:
Consolidate understanding of Kepler laws. Understand and apply concepts of orbital motion and orbit transfers.

Material:
Online version of exercise collection.

Delivery:
Students will hand in proposed exercises.

Full-or-part-time: 1h 30m
Self study: 1h 30m

(ENG) TÍTOL ACTIVITAT 8: SISTEMES DE PARTÍCULES

Description:
Exercises of this chapter will be solved and discussed.

Specific objectives:
Write Newton Laws for systems of particles. Understand and use the concept of linear momentum. Solve variable-mass problems, specifically the rocket equation.

Material:
Online version of exercise collection

Delivery:
Students wwill hand in proposed exercises.

Full-or-part-time: 2h
Guided activities: 2h

(ENG) TÍTOL ACTIVITAT 9: SISTEMA DE COORDENADES MÒBILS

Description:
Exercises of this chapter will be solved and discussed.

Specific objectives:
Know transformations of coordinates between different frames of reference. Calculate the velocity and acceleration of a particle in an accelerating frame. Understand and apply the concept of fictitious forces.
Solve projectile motion nin rotating Earth.

Material:
Online version of exercise collection.

Delivery:
Students will hand in proposed exercises.

Full-or-part-time: 4h
Guided activities: 4h

RIGID SOLID I

Description:
1-dimensional rotation concepts will be reviewed. Moments of inertia will be calculated.

Specific objectives:
Consolidate concepts of 1-dimensional rotation. To be able to calculate moments of inertia.

Material:
Online version of exercise collection.

Full-or-part-time: 2h
Guided activities: 2h

RIGID SOLID ROTATION II

Description:
Exercises about tensors of inertia and Euler equations will be solved and discussed.

Specific objectives:
Consolidate concepts of rigid solid. Solve exerecises involving tensors of inertia and Euler equations.

Material:
Online version of exercise collection.

Delivery:
Students will hand in proposed exercises.

Full-or-part-time: 2h
Self study: 2h

EULER ANGLES AND EULER ANGLE RATES

Description:
Exercises on Euler angles and Euler angle rates will be done and discusses.

Specific objectives:
Visualise and calculate motion in terms of Euler angle and their variation rates.

Material:
Online version of exercise collection

Delivery:
Students will hand in proposed exercises.

Full-or-part-time: 2h
Guided activities: 2h

(ENG) TÍTOL ACTIVITAT 13: CONTROL DE PROBLEMES II

Description:
Test on concepts presented along the course.

Specific objectives:
Let students and teachers probe students learning.

Material:
Hardcopy of test questions

Delivery:
Solved test.

Full-or-part-time: 2h
Guided activities: 2h

(ENG) TÍTOL ACTIVITAT 16: PROJECTE DE L'ASSIGNATURA

Description:
Students will develop a project related to Classical Mechanics in groups of 4

Specific objectives:
Probe students' understanding, as well as their capabilities of analysis and application to practical cases.

Material:
Online version of project proposed

Delivery:
The project and associated test correspond to 20% of the final mark

Full-or-part-time: 10h
Theory classes: 10h

GRADING SYSTEM

Criteria defined at the subject's infoweb will be applied.
-Half term exam (31%) and final exam (39%)
-Test (10%)
-Project and associated test (20%)

EXAMINATION RULES.

All the proposed activities are compulsory. Thus, any activity which is not presented will be marked as 0. Exams and controls will be written individually. Oriented activities and projects will be done either individually or in group, according to the instructions given in each case.

BIBLIOGRAPHY

Basic:
- Meriam, J. L.; Kraige, L.G. Mecánica para ingenieros. Estática [on line]. Reverté, [Consultation: 26/07/2022]. Available on: https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=7723.
- Morin, David. Introduction to classical mechanics : with problems and solutions. Cambridge: Cambridge University Press, 2008. ISBN 9780521876223.
- Riley, William F.; Sturges, Leroy D. Ingeniería mecánica. Vol. 1, Estática. Barcelona [etc.]: Reverté, 1995-1996. ISBN 842914255X.
- Riley, William F.; Sturges, Leroy D. Ingeniería mecánica. Vol. 2, Dinámica. Barcelona [etc.]: Reverté, 1995-1996. ISBN 8429142568.
- Meriam, J. L.; Kraige, L.G. Mecánica para ingenieros. Dinámica [on line]. 3a ed. Barcelona [etc.]: Reverté, 1998-1999 [Consultation: 26/07/2022]. Available on: https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=7722. ISBN 8429142800.
- Symon, Keith R. Mechanics. 3rd ed. Reading, Massachusets [etc.]: Addison-Wesley, 1971. ISBN 0201073927.

Complementary:
- Marion, Jerry B. Dinámica clásica de las partículas y sistemas [on line]. Barcelona: Reverté, 1975 [Consultation: 26/07/2022]. Available on: https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=8702. ISBN 8429140948.
- Lunn, Mary. A First course in mechanics. Oxford [etc.]: Oxford University Press, 1991. ISBN 0198534302.
- Taylor, John R. Classical mechanics. Sausalito, California: University Science Books, 2005. ISBN 189138922X.
- Goldstein, Herbert; Safko, John; Poole, Charles P. Classical mechanics. 3a ed. San Francisco: Addison-Wesley, 2002. ISBN 0201657023.
- French, A. P. Mecànica newtoniana. Barcelona [etc.]: Reverté, 1974. ISBN 8429140999.

RESOURCES

Other resources:
General course on physics with Java applets: http://www.sc.ehu.es/sbweb/fisica/ />