Rational Mechanics (250108)

General Information

School	ETSECCPB
Departments	Departament de Física (FIS) Departament de Física Aplicada (FA) Departament de Física i Enginyeria Nuclear (FEN) Escola Tècnica Superior d'Enginyeria de Camins, Canals i Ports de Barcelona (ETSECCPB)
Credits	7.5 ECTS
Programs	GRAU EN ENGINYERIA CIVIL (pla 2017) GRAU EN ENGINYERIA CIVIL (pla 2010)
Course	2021/22

Main teaching language at each group

- Group 10 language pending definition (Q2)
- Group ENG English (Q2)

Faculty

Responsible Faculty: Juan Jose Sanchez Umbria
Faculty: Alberto Falques Serra, Juan Jose Sanchez Umbria

Objectives of Education

Students will acquire advanced knowledge of general mechanical laws, in particular statics, dynamics and kinematics, and learn how they can be used to solve engineering problems.

On completion of the course, students will have acquired the ability to:
1. Solve kinematic problems of material points and solids;
2. Apply the conservation of mass, momentum and energy equations to material points and solids;
3. Apply mechanical concepts (kinematics, statics and dynamics) to the calculation of basic structures.

Vector algebra, including systems of sliding vectors; Kinematics of material points, trajectories, velocity and acceleration; Newton's laws in inertial and non-inertial systems; Dimensional analysis; Reference systems; Kinematics of solids; Linear and angular momentum; Conservation of momentum; Energy, work and power; Conservation of energy and its application to systems of particles and variable mass systems; Particle, solid and fluid statics; Stress; Equilibrium of solids: Isostatic and hyperstatic problems; Structural statics, including moments of inertia and centres of mass; Three-dimensional solid dynamics

Competencies

Especific

Predictive capacity in civil engineering problems of the concepts of the general laws of mechanics and thermodynamics, fields and waves and electromagnetism .
Capacity for modelling and analytical and computational prediction of the mechanical behaviour of systems.

Transversal

SUSTAINABILITY AND SOCIAL COMMITMENT - Level 1. Analyzing the world¿s situation critically and systemically, while taking an interdisciplinary approach to sustainability and adhering to the principles of sustainable human development. Recognizing the social and environmental implications of a particular professional activity.
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.
EFFECTIVE USE OF INFORMATI0N RESOURCES - Level 2. Designing and executing a good strategy for advanced searches using specialized information resources, once the various parts of an academic document have been identified and bibliographical references provided. Choosing suitable information based on its relevance and quality.
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.

Total hours of student work

		Hours	Percentage
Supervised Learning	Large group	30.0 h	36.36 %
	Medium group	30.0 h	36.36 %
	Laboratory classes	15.0 h	18.18 %
	Guided Activities	7.5 h	9.09 %
Self Study		105.0 h	

Contents

Topic 1: Particle kinematics

Position, velocity and acceleration vectors. Uniform and uniformly accelerated motion.
Circular motion. Angular velocity and acceleration vectors. Intrinsic components of the acceleration. Radius of curvature.
Problems of particle kinematics I.
Integration of the equations of motion in 1D. Change or reference frame: translation.
Problems of the particle kinematics II.

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Topic 2: Particle dynamics

Force and mass. Inertial reference frames and first Newton law. Second and third Newton laws.
Forces at a distance and contact forces. Bonding forces. Friction between solids.
Exercises of particle dynamics I.
Inertia forces. Introduction to dimensional analysis.
Problems of particle dynamics II
Lab experiment on Hooke's law and oscillatory motion

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Topic 3: Systems of forces

Equilibrium of a particle. Equilibrium of rigid bodies: torque of a force. Total force and total torque of a system of forces.
Definition of equivalence and reduction of systems. Invariant trinomium and central axis.
Classification of systems of forces. Planar systems. Examples and exercises.
Exercises on systems of forces

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Exercises on systems of forces

Topic 4: Statics

Equilibrium of systems of solid bodies. Isostatic and hyperstatic problems. Initiation of motion.
Exercises of solid body statics
Continuum systems of forces. Stress vector. Normal and shear stresses. Hydrostatic equilibrium equation.
Buoyancy force. Hydrostatic forces on a solid body.
Exercises on Hydrostatics

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Topic 5: Statics of structures

Equilibrium of articulated structures. Simple planar structures. Analysis by the method of junctions.
Analysis by the method of sections. Examples and exercises.
Exercises on statics of structures
Working in small groups on exercises

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Topic 6: Change of reference frame

Rotation of axes in 3D. Derivative of a vector function. Transformation of velocities and accelerations.
Centripetal and Coriolis accelerations. Inertia forces: centrifugal force and Coriolis force.
Effects of Earth rotation
Exercises on rotating reference frames
Exercises on rotating reference frames II
Summary problems

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Topic 7: Kinematics of rigid bodies

Degrees of freedom of a rigid body. Velocity field. Pure translation and pure rotation. Acceleration field.
Instantaneous axis of rotation and sliding. Motion classification. 2D motion.
Derivative of angles and angular velocity. Composition of rotations. Examples and exercises.
Exercises on 2D kinematics of solid bodies I
Exercises on 2D kinematics of rigid bodies II
Exercises on 3D kinematics of rigid bodies

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Exercises on 2D kinematics of solid bodies I
Exercises on 2D kinematics of rigid bodies II
Exercises on 3D kinematics of rigid bodies

Topic 8: Dynamics of particle systems

Momentum and center of mass. Balance law and dynamics of the center of mass. Impulsive forces.
Orbital and intrinsic angular momentum. Balance law. Central forces.
Exercises on momentum and angular momentum I
Inertia moment.Torque of a force with respect to an axis. Dynamics of planar rotation.
Exercises on momentum and angular momentum II
Exercises on 2D dynamics of rigid bodies
Working session in small groups on problems solving
It is not programmed for this course.

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Topic 9: Work and energy for a particle

Kinetic energy, power and work for a particle. Dissipative and conservative forces.
Conservative fields and potential energy. Potential energy gradient. Theorem of mechanical energy.
Gravitational potential energy and elastic potential energy. Examples and exercises.
Exercises on work and energy for a particle
Analysis of potential energy curves. Equilibrium points and stability. Linearization and small oscillations.
Exercises on stability and small oscillations

Topic 9: Work and energy for a particle

Kinetic energy, power and work for a particle. Dissipative and conservative forces.
Conservative fields and potential energy. Potential energy gradient. Theorem of mechanical energy.
Gravitational potential energy and elastic potential energy. Examples and exercises.
Exercises on work and energy for a particle
Analysis of potential energy curves. Equilibrium points and stability. Linearization and small oscillations.
Exercises on stability and small oscillations

Topic 10: Work and energy for a system

Kinetic energy. Orbital and intrinsic energies. Kinetic energy and work: external work and internal deformation work.
Potential energy of a system of particles. External and internal potential energy. Energy and work for a rigid body.
Exercises on work and energy for systems of particle
Exercises on work and energy for rigid bodies

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Kinetic energy. Orbital and intrinsic energies. Kinetic energy and work: external work and internal deformation work.
Potential energy of a system of particles. External and internal potential energy. Energy and work for a rigid body.
Exercises on work and energy for systems of particle
Exercises on work and energy for rigid bodies

Topic 11: Mass geometry and inertia tensor

Center of mass of continuous bodies. Symmetry properties. Theorems of Pappus-Guldin. Compound bodies and bodies with holes.
Tensor of inertia of a body relative to a point. Angular momentum and kinetic energy of a rigid body. Degeneracy and symmetry properties of the inertia tensor. Steiner theorem. Planar bodies. Extremal property.
Lab experiment on inertia moment
Exercises on mass center computation
Compound bodies and bodies with holes. Inertia tensors of a rod, a rectangle and a parallelepiped. Inertia tensors of a cylinder and a sphere. Inertia moment of planar sections and rod bending.
Exercises on the inertia tensor

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Topic 12: 3D rigid body dynamics

Euler equations. Rotation around a fixed axis. Rotation around a principal inertia axis. Examples.
Simple exercices of 3D rigid body dynamics I
Simple exercices of 3D rigid body dynamics II
Summary exercises

Topic 12: 3D rigid body dynamics

Euler equations. Rotation around a fixed axis. Rotation around a principal inertia axis. Examples.
Simple exercices of 3D rigid body dynamics I
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Summary exercises

Activities

Solving a problem or a test

Solving an exercise or a test.

Dedication

2h

Solving problems or tests

Solving problems or a test.

Dedication

2h

Solving problems or tests

Solving problems or a test.

Dedication

2h

Solving problems or tests

Solving problems or a test.

Dedication

1h 30m

Teaching Methodology

The course consists of:
a) Theoretical lectures. The lecturer exposes the basic concepts and tools, presents examples and solve some exercises.
b) Practical lectures. They are devoted to solving problems with a greater interaction with students. The problems to be solved are previously announced.
c) Lectures in a small group. Of two kinds: i) lab experiments and ii) workshops on solving exercises where a very active participation of students is requiered.
d) Exams and tests. See evaluation method.

There are 3 hours a week of theoretical lectures and 2 hours weekly of practical lessons. These lectures will be distributed according to the time schedule of each group.

The lectures in a small group and the exams will be performed during 'grey hours' of the academic time schedule.

Grading Rules

(*) The evaluation calendar and grading rules will be approved before the start of the course.

The grading of all groups is based on the following tests distributed during the quadrimester:

PR: global mark of the tests done during the classes time,
P1: problems exam (2-3 hours),
P2: problems exam (2-3 hours),

and the grades of the reports of two laboratory classes, L1, L2. None of the tests relieves the student from being asked again about the same topic.

final grade = 0.20*PR + 0.35*(P1+P2) + 0.05*(L1+L2)

Maximum for all grades = 10.

Criteria for re-evaluation qualification and eligibility: Students that failed the ordinary evaluation and have regularly attended all evaluation tests will have the opportunity of carrying out a re-evaluation test during the period specified in the academic calendar. Students who have already passed the test or were qualified as non-attending will not be admitted to the re-evaluation test. The maximum mark for the re-evaluation exam will be five over ten (5.0). The non-attendance of a student to the re-evaluation test, in the date specified will not grant access to further re-evaluation tests. Students unable to attend any of the continuous assessment tests due to certifiable force majeure will be ensured extraordinary evaluation periods.

These tests must be authorized by the corresponding Head of Studies, at the request of the professor responsible for the course, and will be carried out within the corresponding academic period.

Test Rules

Not taking a scheduled exam, without documented justification, implies a cero mark.
The reports of the laboratory experiments will only be considered if the student attends the corresponding laboratory session.

Office Hours

Physics Department, Campus Nord UPC, B5 building.
* Albert Falqués: room 103. Monday, 14:00-15:00; wednesday, 11:00 to 13:00; and to be arranged.
* Joan Sánchez Umbría: room 105. Monday, 15:00-18:00 and to be arranged.

Bibliography

Basic

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Complementary

- Agulló i Batlle, J. Mecànica de la partícula i del sòlid rígid. 3a ed. Barcelona: OK punt, 2010. ISBN 8492085061.
- Meriam, J.L.; Kraige, L.G. Mecánica para ingenieros, vol. 1: Estática. 3a ed. Barcelona: Reverté, 1998-1999. ISBN 8429142576.
- Meriam, J.L.; Kraige, L.G. Mecánica para ingenieros, vol.2: Dinámica. 3a ed. Barcelona: Reverté, 1998-1999. ISBN 8429142592.
- Nelson, E.W.; Best, C.L.; McLean, W.G. Mecánica vectorial: estática y dinámica (SCHAUM). 5a ed. Madrid: McGraw Hill, 2004. ISBN 84-481-2950-4.
- Tippler, P.A. Física para la ciencia y la tecnologia, vols.1 mecánica, oscilaciones y ondas, termodinámica. 6a ed. Barcelona: Reverté, 2010. ISBN 9788429144260.
- Burbano, S.; Burbano, E.; Gracia, C. Física General, vol.1: Estática, cinemática y dinámica. 32 ed. Madrid: Tébar, 2006. ISBN 847360234X.