UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Course guide
240NU211 - 240NU211 - Fusion Technology

Last modified: 20/06/2023

Unit in charge: Barcelona School of Industrial Engineering
Teaching unit: 748 - FIS - Department of Physics.

Degree: MASTER'S DEGREE IN NUCLEAR ENGINEERING (Syllabus 2012). (Optional subject).
MASTER'S DEGREE IN INDUSTRIAL ENGINEERING (Syllabus 2014). (Optional subject).

Academic year: 2023 **ECTS Credits:** 4.5 **Languages:** English

LECTURER

Coordinating lecturer: Futatani, Shimpei

Others: De Blas Del Hoyo, Alfredo
Cortes Rossell, Guillem Pere

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
1. Ability to write the main systems of a nuclear power plant and identify the main features of such systems.
2. Knowledge of different reactor designs and nuclear plants, including proposals for future reactors, and will be able to assess their strengths and weaknesses.

TEACHING METHODOLOGY

1. LECTURES AND CASE EXAMPLES.
Lectures are devoted to form the content of the subject, and some case examples enable to retain and quantify the presented concepts.
These lecture sessions are supported by slides that graphically complement the main ideas of the presentations. The slides are distributed to the students, making easy to follow the explanations.
The "Digital Campus" will be used throughout the course.

2. MULTIMEDIA RESOURCES.
Some technological aspects of the subject are complemented by multimedia projections:
- Magnetic confinement Fusion.
- ITER (International largest fusion project).
- JET, Joint European Torus.

3. PRACTICAL WORK.
Some exercises including calculations may be carried out in the classes.

4. GROUP PROJECT.
Students are assigned to form groups and carry out the investigation of the topic. The groups will present their investigations in the last part of the semester. (40 hours.)

LEARNING OBJECTIVES OF THE SUBJECT

At the end of the course the student will be able:
a) To know the basic physics necessary in order to understand the development of nuclear fusion energy.
b) To provide the state of art of the different technological ways towards the achievement of a commercial fusion reactor.
c) To understand the technological aspects required for the fusion energy production
d) To applied the elemental background and tools for performance evaluations and calculations.
e) To know the ITER project, the technological aspects, the objectives, and the construction schedule (CE8).

STUDY LOAD

Type	Hours	Percentage
Hours large group	36,0	32.00
Hours small group	4,5	4.00
Self study	72,0	64.00

Total learning time: 112.5 h

CONTENTS

1. Introduction

Description:
1.1. Energy Resources.
1.2. Fusion Reactions.
1.3. Fuels.
1.4. Fusion products.
1.5. Thermonuclear fusion history.

Full-or-part-time: 6h
Theory classes: 2h
Self study : 4h

2. Fusion reactions rate

Description:
2.1. Plasma kinetics
2.2. Thermonuclear plasma evolution
2.3. Cross sections
2.4. Two Maxwellian distributions
2.5. A monoenergetic beam and a Maxwelliam distribution
2.6. Fusion reaction rate
2.7. Fusion reaction rate in plasmas with only one kind of particles .
2.8. Power density. Fluency.

Full-or-part-time: 6h
Theory classes: 2h
Self study : 4h

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3. Energy losses

Description:
3.1. Radiative Power losses, Bremsstrahlung
3.2. Cyclotron radiation power loss.
3.3. Recombination
3.4. Charge exchange

Full-or-part-time: 6h
Theory classes: 2h
Self study : 4h

4. Thermonuclear plasma balance

Description:
4.1. Lawson's criteria.
4.2. Conservation equations.
4.3. Thermal equilibrium and ignition temperature.

Full-or-part-time: 6h
Theory classes: 2h
Self study : 4h

5. Plasma confinement systems

Description:
5.1 Introduction. Classification.
5.2. Open systems. Magnetic mirrors: confinement system; simple mirror, lowest B mirror; baseball mirror, Ying-yang mirror.
5.3. Closed systems: Introduction, Stability, Magnetic fields (toroidal, pooidal).
5.4. Tokamaks: JET. Tore-Supra, DIII-D. ITER.
5.5. Stellarators: TJ-II, LHD, Wendeistain 7-AS, Wendeistain 7-X.

Full-or-part-time: 6h
Theory classes: 2h
Self study : 4h

6. Heating systems

Description:
6.1. Ohmic heating.
6.2. Neutral Beam Infection (NBI).
6.3. Adiabatic compression.
6.4. Radio Frequency (RF) heating.
6.5. Relativistic electrons heating.

Full-or-part-time: 6h
Theory classes: 2h
Self study : 4h

7. Plasma impurity. Fuel breeding

Description:
7.1. Impurities: effects, concentrations.
7.2. Helium accumulation.
7.3. Divertors.
7.4. Fuel breeding: gas blanking, NBI's.

Full-or-part-time: 6h
Theory classes: 2h
Self study : 4h

8. Energy extractor systems

Description:
8.1. Fusion reactor's thermohydraulics.
8.2. Blanket design.
8.3. Energy Direct Conversion.

Full-or-part-time: 6h
Theory classes: 2h
Self study : 4h

9. Diagnostic systems

Description:
9.1. Density measurements.
9.2. Temperature measurements.
9.3. Measurements of fusion products.

Full-or-part-time: 6h
Theory classes: 2h
Self study : 4h

10. Neutronics. Tritium production

Description:
10.1. Neutronic flux distribution.
10.2. Tritium production rate.
10.3. Neutron effects on reactor materials.
10.4. Shielding design.

Full-or-part-time: 6h
Theory classes: 2h
Self study : 4h

11. Inertial fusion

Description:
11.1. Introduction.
11.2. Lawson's criteria in ICS.
11.3. Inertial confinement steps.
11.4. Laser fusion: laser. Energy exchange with plasma.
11.5. Particles beams fusion: relativistic electrons, ions.

Full-or-part-time: 6h
Theory classes: 2h
Self study : 4h

12. ITER project

Description:
12.1. Main characteristics.
12.2. Design.
12.3. Construction schedule and planning.
12.4. Operation planning.
12.5. Safety and Environmental Impact.

Full-or-part-time: 6h 30m
Theory classes: 2h
Self study : 4h 30m

ACTIVITIES

Group project

Description:
Students have to form a group which consists of 3-4 students.
Each group will be assigned a topic to investigate.
The students will examine the topic during the semester.
Each group has to submit the report of approximately 15 pages.
Each group has to present their study in the class, about 20-30 minutes, in the end of the semester.

Delivery:
Each group has to submit the report of approximately 15 pages.
Each group has to present their study in the class, about 20-30 minutes, in the end of the semester.

Full-or-part-time: 40h
Self study: 40h

GRADING SYSTEM

The grading method will be:
The mid term exam : 30%
The final exam : 30%
The group project : 20 %
Others (class participation etc) : 20%

NF = 0.3*A1 + 0.3*A2 + 0.2*A3 + 0.2*A4

NF =Final qualification
A1 = Midterm exam result
A2 = Final exam result
A3 = Qualification of the group project
A4 = Qualification of the continuous work participation

BIBLIOGRAPHY

Basic:

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- Dies, J.; Albajar, F.; Fontanet, J. Simulator of nuclear fusion reactor ,tipus tokamak, for educational proposals. Barcelona: UPC. Imatge, 2012.
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- Raeder, J. Controlled nuclear fusion : fundamentals of its utilization for energy supply. New York: Wiley & Sons, cop. 1986. ISBN 0471103128.
- Wesson, John; Campbell, D. J. Tokamaks. 4th ed. Oxford : New York: Clarendon Press ; Oxford University Press, cop. 2011. ISBN 9780199592234.

Complementary:

- Hutchinson, I. H. Principles of plasma diagnostics. 2nd ed. Cambridge: Cambridge University Press, 2002. ISBN 9780521675741.
- Wakatani, Masahiro. Stellarator and Heliotron Devices. Oxford: Oxford University Press, 1998. ISBN 9780195078312.
- Adam, M.M.J. La Fusion thermonucléaire contrôlée par confinement magnétique. Paris: Masson, 1987. ISBN 2225812845.
- Kammash, Terry. Fusion reactor physics : principles and technology. Michigan: Ann Arbor Science, 1977.
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