Degree: Industrial Engineer

ETSEIB

4r Q7	25336 **NUCLEAR REACTOR PHYSICS**

Department:	721 Nuclear Physics & Engineering		
Coordinator:	Javier Dies		Pab. C floor 0
Type	Credits Theory / Problems / Laboratory:	3 / 1 / 2	
OPTATIVE	European Credits ECTS	5	Language: Spanish

OBJECTIVES

Main objective

To present the basic elements for the understanding of the production process and fission energy profit, which are mainly related to the nuclear reactor.

Specific objectives

- To provide the basic elements for the understanding of the production process and fission energy profit, which are mainly related to the nuclear reactor.
- To introduce the technological aspects associated to the reactor core.
- To give the basic foundations of calculation and evaluation.
- To present the basic nuclear fuel cycle elements.

CONTENTS

-. (1h) **Subject presentation.** (Prof. J. Dies)

0. (2 h) **Introduction to the Nuclear Energy**. Nuclear reactor operation principle. Historical introduction and current situation of the fission nuclear energy profit. -M0- (Prof. J. Dies)

1. (2 h) **Neutron interaction**. Reactions types. Cross sections according to the energy. Neutron scattering. Moderation power and reason. Westcott factors. -M1- (Prof. J. Dies)

2. (2 h) **Fission process in a nuclear reactor**. Fission reaction. Conversion and reproduction. Fission energy. Nuclear reactor power. Fuel consumption, fission products. - M2- (Prof. J. Dies)

3. (2h) **Neutron multiplication in a nuclear reactor**. The multiplication factor. The four and six factors formula. Critical mass. - M3- (Prof. J. Dies)

4. (2h) **Neutron balance in an material medium**. Neutron transport theory. Transport equation solutions. Neutron diffusion theory. Fick's law. Validity conditions. Physical interpretation. Limit Conditions. (Prof. J. Dies)

5. (2h) **Neutron moderation in non absorbent infinite environments**. Hydrogen situation. Asymptotic solution. Finite environmental moderation. Fermi age model. Absorbent environmental moderation. (Prof. J. Dies)

6. (3 hr) **Criticality in multiplier medium.** Multiplication coefficient**.**Criticality of the bare homogeneous reactor. Criticality calculation by using of the multigroup model. Criticality determination with reflector. (Prof. J. Dies)

7. (2 hr) **Reactor kinetics**. Delayed and non delayed neutrons. Reactivity equation for six delayed neutron groups. Small reactivities. Flux evolution. -M4- (Prof. J. Dies)

8. (2 hr) **Control rod effect.** Control-rod Worth. Differential and integral value. -M5- (Prof. J. Dies)

9. (1h) **Soluble poisons.** Reactivity effect calculation.–M6- (Prof. J. Dies)

10. (1h) **Burnable poisons.** Location. Reactivity effect calculation. –M7- (Prof. J. Dies)

11. (2h) **Reactivity temperature effects.** Feedback coefficients. Stability. Fuel temperature coefficient. Moderator temperature coefficient. –M8- (Prof. J. Dies)

12. (4h) **Core Thermal-hydraulics.** Energy balance. Cell radial problem. Axial channel problem. Hot channel factors. Hydrodynamic problem. Calculation codes. (Prof. F. Reventos)

13. (2h) **Fission products poisoning. Dead Time**. Xenon space oscillations. Samarium effects . – M9- (Prof. J. Dies)

14. (2h) **Neutron Sources.** Intrinsic and external sources. Sub critical multiplication. Bending curves. -M10- (Prof. J. Dies)

15. (3h) **Nuclear fuel cycle**. Mining, isotopic enrichment. Fuel burn up. Waste management. (Prof. J. Dies)

METHODOLOGY

1. Theory and exercises.

The contents of the different lessons that constitute the program are exhibited in the classroom. There are insertions of exercises for the accomplishment of fixing and quantifying the presented concepts.

To improve the operation of these sessions the professor usually uses the multimedia on Nuclear Reactor Physics with video-projector. This multimedia allows the main ideas about the exhibition graph enrichment. With sufficient anticipation, a copy is distributed to the students in paper and in cd. This copy makes easier to focus the attention on the explanations, without having to take excessive annotation.

For the follow-up of the subject development also the digital campus will be used.

2. NUCLEAR REACTOR PHYSICS MULTIMEDIA.

It has been carried out the Multimedia of Nuclear Reactor Physics in collaboration with the Tecnatom S.A. enterprise and the ETSEIB's Multimedia Laboratory. The Multimedia objective is to integrate the new technologies to enrich and to give impulse to the teaching in the subjects. This multimedia will help the students deepen in the matter with greater easiness, as well as increase their motivation. In the contents relation, the M5 note indicates the match with the Multimedia chapter 5.

3. EXPERIENCES.

3.1. Nuclear Power Plant Conceptual Simulator DFEN-ETSEIB-UPC.

The Nuclear Power Plant Conceptual Simulator DFEN-ETSEIB-UPC has been created backed by the Consejo de Seguridad Nuclear, for the ETSEIB, for the Nuclear Association Ascó-Vandellos II, and with the collaboration of the "International Atomic Energy Agency". Conceptual Simulator SIREP reproduces a reactor PWR 1350 MWe of 4 loops. (Prof. J. Dies)

http://www-sen.upc.es/Situacion/Sim_Con_CenNu.htm

The experiences are developed by the students individually.

Ten practices with the simulator SIREP, five within this subject framework and five in the Nuclear Power Plants subject of fifth course will be carried out.

According to this subject's five experiences:

practice P1: **Reactor kinetic parameters**. Instantaneous neutrons and delayed neutrons. Kinetics equations. Reactor's period and bending time. Estimation of the proportion of delayed neutrons. Prompt Jump. (Prof. J. Dies)

practice P2: **Subcritical approach**. Reactor shutdown states. Hot and cold shutdowns. The multiplication subcritical factor calculation. Starting sources. Boron dilution. Reactivity evolution after refueling. Chemical and volume control system. (Prof. J. Dies)

practice P3: **Reactivity temperature effects**. Feedback concept. Temperature's feedback. Doppler effect and Moderator effect. Feedback coefficients calculation. Influence on the reactor stability. (Prof. J. Dies)

practice P4: **Isothermal coefficient and moderator coefficient**. Moderation relation. Isothermal coefficient and moderator coefficient determination. Design principle of intrinsic security. Boron limit concentration determination. (Prof. J. Dies)

practice P5: **Starts and reactor load variations.** Reactivity balances. Poisoning effects. Xenon-135 and samarium-149 in the fuel production. Antireactivity. The poisoning effect control. Application to a reactor power drop. (Prof. J. Dies).

(10 hours)

Experiences development methodology:

- Nuclear Power Plant Conceptual Simulator DFEN-ETSEIB-UPC professor presentation: reach, used models and required data bases.
- Simulator operation: Parameters definition, entering data, obtained data store.
- Results analysis.
- Raised questions resolution and memory elaboration.

3.2. Full Scope Nuclear Power Plant Simulator Use in the Tecnatom Formation Center in Hospitalet del Infant (Tarragona).

It has been programmed to make a practice in the Tecnatom Formation Center in Hospitalet del Infant (Tarragona) thanks to the Company Tecnatom S.A collaboration, where two of Full

Scope Nuclear Power Plants Simulators have been settled. These simulators reproduce on scale the 1:1 the control room of the N.P.P. of Vandellos II and the N.P.P. of Asco.

P6AT: In this experience, it is reached the initial core criticality after a fuel reload. (Prof. J. L. Delgado, Tecnatom S.A.).

The criticality will be obtained taking the D control bank to the calculated position after having adjusted the boron concentration of the reactor cooler in its calculated criticality value.

Objectives:

- To know the manoeuvres which are carried out to reach the initial criticality.
- To know how the initial reactor criticality is determined, through the observation of parameters in the control room.
- To understand how the criticality can be predicted with the graphs of inverse counting.
- To carry out the inverse counting of approach to criticality graphs.

The students report, once the experience has been carried out, will have to include:

- Data sheet with the annotations made in the control room.
- Inverse counting graph carried out with regard to the position of the control rods.
- Significant parameter evolution graphs, to be determinate by the student.
- Analysis and comments on the obtained results

(Duration: 3 hrs + trips)

3. MONOGRAPHIC REPORTS:

Six monographic works are made In order to foment the concepts fixation exposed in the theoretical classes. The student makes calculation and certain extension designs with the support of the professor.

TP1. (2 h) Power generation and fuel evolution with the burn up. (Prof. J. Dies)
TP2. (2 h) Homogeneous sphere reactor design. (Prof. J. Dies)
TP3. (2 h) Homogeneous reactor with reflector design. (Prof. J. Dies)
TP4. (2 h) Thermal hydraulic core PWR reactor calculation. (Prof. F. Reventos)

(duration: 8hr)

5. TECHNICAL VISIT:

- VT1: A visit to a Nuclear Power Plant is carried out in every academic course. Thus, it is visited Vandellòs II Nuclear Power Plant (1087,1 MWe) and the following one is visited the Ascó I and II Nuclear Power Plant (1032,5 MWe and 1027,2 MWe respectively) in Tarragona. There are highlighted the aspects related to the reactor core. http://www.anav.es
    - Asociation Nuclear Ascó-Vandellòs Presentation (AIE)
    - Nuclear Power Plant Presentation
    - Control Room
    - Fuel Building
    - Turbine Building
    - Diesel Building
    - Refrigeration System
    - Transformer Station.

(Duration: 5 hrs + trip)

EVALUATION

The evaluation system used in the subject tries to the learning quality improvement. This is carried out by encouraging a continuous work to the student and the development of practical activities, according to the norms fixed by the ETSEIB's current study plan.

The evaluation is carried out assigning a weight of 50% to the continuous evaluation (NAC) and a weight of 50% to the evaluation of the practical teachings (NAEP). The evaluation of the theoretical topics is based in two tests. The first is made after having exposed about four subjects (NACET). The second test will include the entire program and will be carried out at the end of the course (NE). The evaluation of the practical experiences will be developed from the memories presented by the students. These memories are related to every practical work (MP), the assistance to the practices (AP) and the participation in the technical visit (V). The final qualification (NF) will be obtained with the following expression:

$NF = r * NE + (1- r) * NAC$ $\quad r = 0,5$
$NAC = q * NAEP + (1- q) * NACET$ $\quad q = 0,5$
$NAEP=1/2* MP + 1/4* AP + 1/4*V$

NF = Final Mark
NE = Exam Mark
NAC = Continuous Evaluation
NAEP = Practical Teachings Mark
NACET = Theoretical Continuous Teachings Mark

This subject evaluation will be part of the curricular evaluation of the student corresponding to the curricular block. Its efficiency is evaluated in all the subjects that constitute this curricular block, according to the ETSEIB's Non Selective Phase Norm of Evaluation.

Norms of tests accomplishment:

The evaluations will have a part of basic concepts that students will realize without notes and another part based on exercises in which documentation will be allowed. The part of exercises can contemplate the analysis of a sceranio with the Nuclear Power Plant Conceptual Simulator.

RESOURCES:

Main Bibliography.

1. LAMARSH, J. R. " Introduction to Nuclear Reactor Theory ". Addison Wesley Co. 1975.
2. DIES, J.; PUIG, F.; PEREIRA, C.; "Multimedia de Física de Reactores Nucleares ", pag. 600, Barcelona, 2004.
3. DIES, J.; PUIG, F.; PEREIRA, C.; "Multimedia de Física de Reactores Nucleares ", cd-rom, Barcelona, 2004.
4. DIES, J.; TAPIA, C.; PUIG, F.; VILLAR, D.; "Programa de formación prática en el área de Ingenieria Nuclear mediante el Simulador Conceptual de Central Nuclear DFEN-ETSEIB-UPC", pag. 176, Barcelona 2005.

5. MARTINEZ-VAL, J.M. "Reactores Nucleares". Ediciones ETS Ingenieros Industriales de Madrid. 1997.
6. DUDERSTADT, J. ; HAMILTON, L. " Nuclear Reactor Analysis ". Jhon Wiley & Sons,1976.
7. REUSS, P.; “Exercices de neutronique”, Gene Atomique, INSTN, EDP Sciencies, Francia, 2004.

Complementary Bibliography:

8. BARJON, R. " Physique des Reactors Nucleaires ". Institut des Sciences Nucleaires, 1993.
9. KARL O. OTT. " Introduction Nuclear Reactor Statics ". Library of Congress, ed. 1989.
10. GLASSTONE, S.; SESONSKE, A. " Nuclear Reactor Engineering ". Chapman and Hall 4th. ed. 1994.
11. MUÑOZ-COBO, J.L.; ESCRIVA, A. “Apuntes de Termohidráulica”. SPUPV-99.194, Editorial de la Universidad Politécnica de Valencia.
12. TODREAS, N.E. ; KAZINI, M.; “Nuclear Systems I, Thermal hydraulic fundaments”, Taylor & Francis 1989.
13. HENRY, A.F.; "Nuclear Reactor Analysis", MIT, Press, 1982.
14. BELL, G.I., GLADSTONE, S.; "Nuclear Reactor Theory", Van Nostrand-Reinhold, 1971.
15. LEWINS, J.; "Nuclear Reactor Kinetics and Control", Pergamon, Oxford 1978.
16. OTT, K.O., BEZELLA, W.A., "Introductory Nuclear Reactor Statics" , ANS 1989.
17. OTT, K.O., NEUTHOLD, R.J. "Introductory Nuclear Reactor Dynamics", ANS, 1985.

Reviews:
1. Nuclear Technology.
2. Nuclear Engineering International.
3. Nuclear Engineering and Design
4. Nuclear Safety
5. Nuclear España
6. Seguridad Nuclear.

Computer Material:
Links : http://www-sen.upc.es

Campus Digital

La Universidad Politécnica de Cataluña has developed the computer environment ATENEA on which the ETSEIB has implemented its *Campus Digital*.

To increase the communication between the student and the professor, it will be used in this subject the Digital Campus, as an additional environment of asynchronous communication.

The usual uses of the ETSEIB ‘s Campus Digital in the subject Nuclear Reactors Physics are:
- Show the qualifications of the students in the different evaluation acts.
- Announcement of conferences, video conferences and seminaries.
- Announcement of changes of dates or hours, in the subject program: practices, technical visits, evaluations.
- Agreeing on interviews between professor and student.
- Viewing the curricular marks of the student.
- Documentation distribution.
- General advertisements (work offers, scholarships offers, news related to the nuclear engineering..)

TEACHING STAFF AND ATTENTION SCHEDULE

An interview with the coordinator professor can be agreed on through: electronic mail, telephone, when finishing the class or in the Nuclear Department secretary (pavilion C, ETSEIB).

Professor:

- Javier Dies: Javier.Dies@upc.edu Tel. 934017144.

EUROPEAN MASTER OF SCIENCE IN NUCLEAR ENGINEERING (EMSNE):

The five ECTS corresponding to this subject count for the obtaining of the European Master of Science in Nuclear Engineering (EMSNE) from the European Nuclear Education Network (ENEN).

http://www-sen.upc.es

SCHEDULE COURSE 2005-2006:

There are classes on Mondays and Wednesdays from 12h to 14h PM, from September 12 to December 22 of the 2005.