BNEN

Belgian Nuclear higher Education Network (BNEN)

Master after Master in Nuclear Engineering

UNIVERSITEIT GENT

LIÈGE université

UCLouvain

sck cen

ULB

VUB VRIJE UNIVERSITEIT BRUSSEL

KU LEUVEN

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INTRODUCTION

BNEN, the Belgian Nuclear higher Education Network was created in 2001 by five Belgian universities and the Belgian Nuclear Research Centre (SCK CEN), as a joint effort to maintain and further develop a high-quality programme in nuclear engineering in Belgium. The current consortium was established in 2006 when the sixth partner university joined the programme. Public authorities, regulators and industry brought their support to this initiative.

In the framework of the architecture of higher education in Europe, the English name for this 60 ECTS programme is "Master of Science in Nuclear Engineering". To be admitted to this programme, students must already hold a university degree in engineering science or equivalent. For students not fully meeting this requirement, special admission consideration applies as explained further in this brochure.

The master after master programme is a demanding programme where students with different high level backgrounds in engineering have to go through highly theoretical subjects like neutron reactor physics, fluid flow and heat transfer modelling, and apply them to reactor design, nuclear safety and plant operation & control. At a more interdisciplinary level, the programme includes important chapters of material science, with a particular interest for the fuel cycle. Radiation protection also belongs to the backbone of the programme. To meet the future nuclear competences needed in the broader nuclear context, the programme also tackles decommissioning and waste & disposal and integrates a module on societal aspects of nuclear applications. The full programme is hosted in Mol, Belgium. All subjects are taught by academics appointed by the partner universities. The practical exercises and laboratory sessions are supervised by researchers of SCK CEN. The final thesis offers an opportunity for internship in industry or in a research laboratory. The programme structure includes the possibility to spread it over two years, especially to accommodate young professionals.

Linked with university research, benefiting from the human resources and infrastructure of SCK CEN, encouraged and supported by the partners of the nuclear sector, this programme is offered not only to Belgian students, but also more widely throughout Europe and the world. From the start this international aspect was taken into account by, in parallel to BNEN, establishing ENEN. Today, the European Nuclear Education Network consists of about 60 universities and other stakeholders such as industry, regulators, and research centres and it is strongly supported by the European Commission. Its formal seat is in Brussels, and BNEN is the Belgian pole of this network. Students registering to any of the participating institutions are offered the opportunity to coherently take a part of their basic nuclear education at different places in Europe while cumulating credit units. Practical laboratory sessions and advanced subjects taught in a modular way are also offered to enrich the programmes. A special qualification of "European master" is awarded to the students who have obtained their degree with a substantial effort of mobility.
BNEN is open to receive European students and all BNEN students are strongly encouraged to include a period of training abroad, to benefit from the multiple opportunities created by ENEN.

INTRODUCTION

With this BNEN Master of Science in Nuclear Engineering, we deliver highly qualified engineers required for the safe and economic operation of the nuclear power plants in Belgium and abroad, and for the broader nuclear-related industry, healthcare, research and governmental institutions.

BNEN STEERING COMMITTEE

For the academic year 2020-2021

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BNEN SHARE OF TEACHING RESPONSIBILITIES

	ECTS	KU Leuven	UGent	VUB	UC Louvain	ULB	ULiège	Titular
Compulsory modules	**31**							
Introduction to nuclear energy	3	3						William D'HAESELEER
Introduction to nuclear physics and nuclear measurements	3					3		Nicolas PAULY
Nuclear materials	3	2					1	Marc SCIBETTA Rik-Wouter BOSCH Eric VAN WALLE
Nuclear fuel cycle	3						3	Hubert DRUENNE Christophe BRUGGEMAN
Radiation protection	3		3					Klaus BACHER
Nuclear thermal hydraulics	5				5			Yann BARTOSIEWICZ
Nuclear reactor theory	6	2	2	2				William D'HAESELEER Jean-Marie NOTERDAEME Peter BAETEN
Safety of nuclear power plants	5		3			2		Hubert DRUENNE Pierre-Etienne LABEAU
Elective modules (9 ECTS to be chosen from the list below)	**9**							
Advanced nuclear reactor physics and technology	3				3			Hamid AIT ABDERRAHIM
Advanced nuclear materials	3	2					1	Marc SCIBETTA Rik-Wouter BOSCH Eric VAN WALLE
Advanced radiation protection radiation ecology	3		3					Klaus BACHER
Advanced courses of the nuclear fuel cycle	3						3	Hubert DRUENNE Christophe BRUGGEMAN
Nuclear and radiological risk governance	3		1		2			Fernand VERMEERSCH Greet MAENHOUT
Advanced course elective topic	3			3				Peter BAETEN
Master thesis	**20**							
Total	**60**							

BNEN ADMISSION CRITERIA

The BNEN programme has a limited capacity of enrollment, as lab sessions are organized at the premises of the SCK CEN research centre, using its experimental facilities.
Consequently, all admissions are conditional and subject to a decision by the BNEN Steering Committee. Admission to the BNEN programme can be considered for the following possibly eligible cases:

- the holders of an academic degree of "master en sciences de l'ingénieur, orientation Ingénieur civil" from the "Communauté française de Belgique" or an academic degree of « Master of science in de ingenieurswetenschappen (burgelijke ingenieur)" from the "Vlaamse Gemeenschap van België", given a sufficient scientific/technical background required for the BNEN courses, whereby the BNEN Steering Committee may impose additional background courses (for a maximum number of 15 ECTS), taking into account the contents of the curriculum already completed;

- the holders of an academic degree similar and considered equivalent to those mentioned above, under the same conditions;

- the holders of an academic degree similar and considered equivalent to those mentioned above, delivered by the Royal Military School, under the same conditions.

- the holders of an academic degree of "master en sciences industrielles ou de MA en sciences de l'ingénieur industriel" from the "Communauté française de Belgique" or an academic degree of "master in de industriële wetenschappen, industrieel ingenieur" from the "Vlaamse Gemeenschap van België", whereby the BNEN Steering Committee will impose an additional set of background courses (for a maximum number of 60 ECTS), taking into account the contents of the curriculum already completed, and whereby previously relevant background courses may be valorized and accepted for credit transfer[1];

    - If the student registers in an institution of the "Communauté française de Belgique", these additional credits are then part of the « master de spécialisation » the student will enroll in and they are a prerequisite for the regular BNEN programme of 60 ECTS.
    - If the student registers in an institution of the "Vlaamse Gemeenschap van België", these additional credits are part of a preparatory programme, before possibly being admitted to the BNEN programme of 60 ECTS.

[1] As an example, typical "preparatory programmes" amount to about 30 ECTS for applicants with an electro-mechanical background. For applicants with a different background, like ICT, the "preparatory programme" may be close to 60 ECTS.

- the holders of an academic degree of "master en sciences chimiques, physiques, mathématiques ou informatiques" or "master en sciences de l'ingénieur orientation bioingénieur" from the "Communauté française de Belgique", or an academic degree of "master in de chemie, in de fysica, in de wiskunde of in de informatica" or "master in de bio-ingenieurswetenschappen" from the "Vlaamse Gemeenschap van België", or holders of an academic degree similar and equivalent to those just mentioned, whereby the BNEN Steering Committee will impose an additional set of background courses (for a maximum number of 60 ECTS), taking into account the contents of the curriculum already completed, and whereby previously relevant background courses may be valorized and accepted for credit transfer[2];
    - If the student registers in an institution of the "Communauté française de Belgique", these additional credits are then part of the « master de spécialisation » will enroll in student and they are a prerequisite for the regular BNEN programme of 60 ECTS.
    - If the student registers in an institution of the "Vlaamse Gemeenschap van België", these additional credits are part of a preparatory programme, before possibly being admitted to the BNEN programme of 60 ECTS.

- the holders of a foreign academic degree judged similar to the academic degrees delivered by either the "Communauté française de Belgique" or the "Vlaamse Gemeenschap van België", mentioned in the above items, under the same conditions (i.e. basic master programme of at least 300 ECTS and depending on the acquired background in the curriculum and the level of abstraction) and according to the prescriptions of the respective decrees;

The clearance to access the control zone of the SCK CEN is delivered by the Federal Agency for Nuclear Control (FANC) and must be obtained to take part in laboratory sessions of the BNEN programme. **This clearance by FANC is a precondition to the BNEN programme and as such, all "admissions" given by the BNEN Steering Committee are conditional and thus "provisional". The "provisional"** admission will be automatically cancelled if this clearance is not timely received by the student.

[2]As an example, typical "preparatory programmes" amount to about 30 ECTS for applicants with a physics background. For applicants with a different background, like ICT, the "preparatory programme" may be close to 60 ECTS.

Typical BNEN "preparatory" program for applicants holding a degree Master in Engineering Technology and Master in (Basic) Sciences

As an example, the students holding an above mentioned degree are required to register for a set of courses at the university of her/his choice (in principle covering the study of about 30 ECTS points) as approved by the Teaching Committee of BNEN, and to take the exams. Upon successfully passing the exams, the student can be formally admitted to the BNEN programme.
Depending on the university chosen and on the student background, the preparatory courses may be different. Hereunder, an example for the KU Leuven is given. As a guideline, the "preparatory programme" to be followed by a holder of a master degree in Engineering Technology (so-called 'industrial engineers') to obtain the master in engineering science is taken as a basis. However, depending on the courses taken towards the earlier degrees, the set of courses may have to be be adjusted.

Bridge programme BNEN at KU Leuven

All (basic bachelor) courses are taught in Dutch, but lecturers will assign a good English textbook (which covers the same material as in their own courses) and examine the students in English. After advice by the KU Leuven Programme Director, non-Dutch speaking students will have to contact the instructors by mail to set up an appointment or to make arrangements by mail or phone.

Programme for students with engineering technology background (foreign students & "Industrial Engineers" from Belgian University campuses)

1. H08W4A (3 ECTS - W. D'haeseleer)
Fluid Mechanics / Fluidummechanica
https://onderwijsaanbod.kuleuven.be//syllabi/v/e/H08W4AE.htm#activetab=doelstellingen_idp1627360
http://onderwijsaanbod.kuleuven.be/syllabi/n/H08W4AN.htm

2. H08W5A (3 ECTS – W. D'haeseleer)
Heat Transfer / Warmteoverdracht
https://onderwijsaanbod.kuleuven.be//syllabi/v/e/H08W5AE.htm#activetab=doelstellingen_idp605584
http://onderwijsaanbod.kuleuven.be/syllabi/n/H08W5AN.htm

3. H01N2A (6 ECTS – M. Baelmans)
Energy Conversion Machines and Systems / Energieconversiemachines en systemen
https://onderwijsaanbod.kuleuven.be/syllabi/v/e/H01N2AE.htm#activetab=doelstellingen_idp1458496
http://www.kuleuven.ac.be/onderwijs/aanbod/syllabi/H01N2AN.htm

4. H0M71A (5 ECTS) M. Van Barel
Numerical Mathematics / Numerieke wiskunde
https://onderwijsaanbod.kuleuven.be/syllabi/v/e/H0M71AE.htm#activetab=doelstellingen_idp61424 http://www.kuleuven.ac.be/onderwijs/aanbod/syllabi/H0M71AN.htm

5. H0M69A (6 ECTS – R. Cools)
Applied Algebra and Differential Equations / Toegepaste algebra en differentiaalvergelijkingen
https://onderwijsaanbod.kuleuven.be/syllabi/v/e/H0M69AE.htm#activetab=doelstellingen_idm1177616
http://www.kuleuven.ac.be/onderwijs/aanbod/syllabi/H0M69AN.htm

6. H01M8A (6 ECTS – B. De Moor)
System Theory and Control Theory / Systeemtheorie en regeltechniek
https://onderwijsaanbod.kuleuven.be/syllabi/v/e/H01M8AE.htm#activetab=doelstellingen_idp2651360
http://www.kuleuven.ac.be/onderwijs/aanbod/syllabi/H01M8AN.htm

Programme for students with a background in physics, mathematics or chemistry

1. H01L8A (6 ECTS – J. Driesen)
Electrical Energy and Drives / Elektrische Energie en aandrijvingen
https://onderwijsaanbod.kuleuven.be/syllabi/v/e/H01L8AE.htm#activetab=doelstellingen_idp5742848
http://www.kuleuven.be/onderwijs/aanbod/syllabi/H01L8AN.htm

2. H08W4A (3 ECTS - W. D'haeseleer)
Fluid Mechanics / Fluidummechanica
https://onderwijsaanbod.kuleuven.be//syllabi/v/e/H08W4AE.htm#activetab=doelstellingen_idp1627360
http://onderwijsaanbod.kuleuven.be/syllabi/n/H08W4AN.htm

3. H08W5A (3 ECTS – W. D'haeseleer)
Heat Transfer / Warmteoverdracht
https://onderwijsaanbod.kuleuven.be//syllabi/v/e/H08W5AE.htm#activetab=doelstellingen_idp605584
http://onderwijsaanbod.kuleuven.be/syllabi/n/H08W5AN.htm

4. H01N2A (6 ECTS – M. Baelmans)
Energy Conversion Machines and Systems / Energieconversiemachines en systemen
https://onderwijsaanbod.kuleuven.be/syllabi/v/e/H01N2AE.htm#activetab=doelstellingen_idp145849
http://www.kuleuven.ac.be/onderwijs/aanbod/syllabi/H01N2AN.htm

5. H01M8AN (6 ECTS – B. De Moor)
System Theory and Control Theory / Systeemtheorie en regeltechniek
https://onderwijsaanbod.kuleuven.be/syllabi/v/e/H01M8AE.htm#activetab=doelstellingen_idp2651360
http://www.kuleuven.ac.be/onderwijs/aanbod/syllabi/H01M8AN.htm

6. H9XA1A (3 ECTS – N.)
Construction Materials / Constructiematerialen
https://onderwijsaanbod.kuleuven.be/syllabi/v/e/H9XA1AE.htm#activetab=doelstellingen_idm16962320
http://www.kuleuven.be/onderwijs/aanbod/syllabi/H9XA1AN.htm

7. H01D0A (E ECTS – B. Blanpain)
Introduction to Material Science / Inleiding tot de materiaalkunde
https://onderwijsaanbod.kuleuven.be/syllabi/v/e/H01D0AE.htm#activetab=doelstellingen_idm17492896
http://www.kuleuven.be/onderwijs/aanbod/syllabi/H01D0AN.htm

For an exemplary (but non-exhaustive) list of typical reference books on BNEN prerequisites: http://bnen.sckcen.be/.

GENERAL INFORMATION

Application process

STEP 1: Acceptance by the BNEN Teaching Committee

An application file consists of, at least:

- the registration form;
- a motivated application letter;
- a curriculum vitae;
- transcripts of academic results;
- when applying for a grant, a declaration of the non-employment situation (limited number of grants).

See also: https://bnen.sckcen.be/en/Application/Application_process. For convenience an sample application form is part of this Brochure on page 21.

STEP 2: Registration in one of the six partner universities

After approval by the Teaching Committee students need to register at one of the three Flemish universities or at the 'referent' university of the French speaking community.

Pay attention to all the registration procedures at your university. There can be problems when you want to spread the programme over more than 1 year. The processes at the Flemish universities are different than the ones at the French speaking community of the country. For more information, contact the administration department of the university of your choice. (Contact persons can be provided by the BNEN secretariat: bnen@SCKCEN.be.)

STEP 3: Access to the Belgian Nuclear Research Centre

All candidates will be screened by the Belgian Federal Agency for Nuclear Control for clearance and access to the nuclear infrastructure of SCK CEN. Final admission to the programme is subject to clearance and access being granted.

BNEN academic calendar

- Start: End of September
- 17 weeks of courses
- 13 weeks for project work and examinations

For a detailed calendar: consult http://bnen.sckcen.be.

What are ECTS credits?

ECTS credits are a value allocated to course units to describe the average student workload required to complete them successfully. They reflect the quantity of work each course requires in relation to the total quantity of work required to complete a full year of academic study at the institution, that is, lectures, practical work, seminars, private work – in the laboratory, library or at home – and examinations and other assessment activities.

In ECTS, 60 credits represent one year of study (in terms of workload); normally 30 credits are given for six months (a semester) and 20 credits for a quarter (a trimester).

ECTS credits are also allocated to internships and to thesis preparation when these activities form part of the regular programme of study at both the home and host institutions.

ECTS credits are allocated to courses and are awarded to students who successfully complete those courses by passing the examinations or other assessments.
Ref.: http://ec.europa.eu/education/ects/ects_en.htm

How to translate ECTS in workload - hours?

60 ECTS – 1 year workload or 40 weeks x 45 hours/week = 1 800 hours.

3 ECTS credits represent an estimated workload of 90 hours for the student.

As a guideline: 3 ECTS = 1 teaching module = 20 hours of lectures + 10 hours e.l.s.
(e.l.s. = exercises, laboratory sessions, seminars).

For a 3-ECTS course, these 90 hours might be rated as:

- 20 hours lectures x 3.5 = 70 hours. The factor 3.5 is applied as the 'standard' student needs another 2.5 hours to assimilate what has been taught in one hour. This factor also depends on the teaching pace. Some universities foresee more contact hours and integrate more examples/exercises and apply a factor of 2.5 or 3.
- 10 hours e.l.s. x 1.5 = 15 hours. Laboratory sessions and/or exercises, without too much of reporting, get a factor 1. With reporting: 1.5.
- 5 hours additional independent reading/study.
- In summary: 70 hours + 15 hours + 5 hours = 90 hours.

Advanced course 'elective topic', e.g. two topical days of 1.5 ECTS or 45 hours each:

- 8 hours lectures x 1.5 = 12 hours
- 9 hours understanding & 'assimilating' the workshop material (e.g., slides)
- 12 hours report preparation / literature search = 12 hours

- 12 hours actual writing of report = 12 hours
- In summary: 12 hours + 9 hours + 12 hours + 12 hours = 45 hours
- Remark: reports of 10 to 20 pages, to be handed in six weeks after the event.

Exemptions

Students can ask for an exemption for a particular course or a part of the course.
This request should be submitted in time to the BNEN Teaching Committee.

Prior to a formal positive decision from the Teaching Committee concerning the requested exemption, students must assume they have to take the course(s).

Note that a only a maximum of 6 ECTS (credits) can be granted; more 'earlier-background exemptions' must be compensated by an elective course.

BNEN laboratory sessions

- Most courses include exercises, laboratory sessions and/or seminars (e.l.s.).
- **Attendance to exercises, laboratory sessions, seminars is compulsory** (2nd Teaching committee meeting dd. October 22, 2002). It is strongly recommended to take the else with the course. However in case of motivated "non-possimus", an else attendance might be shifted to another occasion, possibly to the next year.
- The academic responsible for the course decides on the reporting (number of pages, deadline) as well as on the weight of the else in the final quotation of the overall course.

Quality

Quality Assurance (QA) has been emphasized from the beginning in this interuniversity programme. Both the programme as a whole and the different courses individually have been and are being evaluated on a regular basis. For the QA aspect of curriculum and programme monitoring, the BNEN Steering Committee plays the leading and a nearly independent role. The BNEN tools for evaluations and QA exist on top of the QA policy of the individual universities and of SCK CEN.

QA is a fixed agenda point on each Steering Committee meeting. The BNEN vice-chairperson is appointed as QA responsible for the programme. The BNEN secretary acts as Ombudsperson.

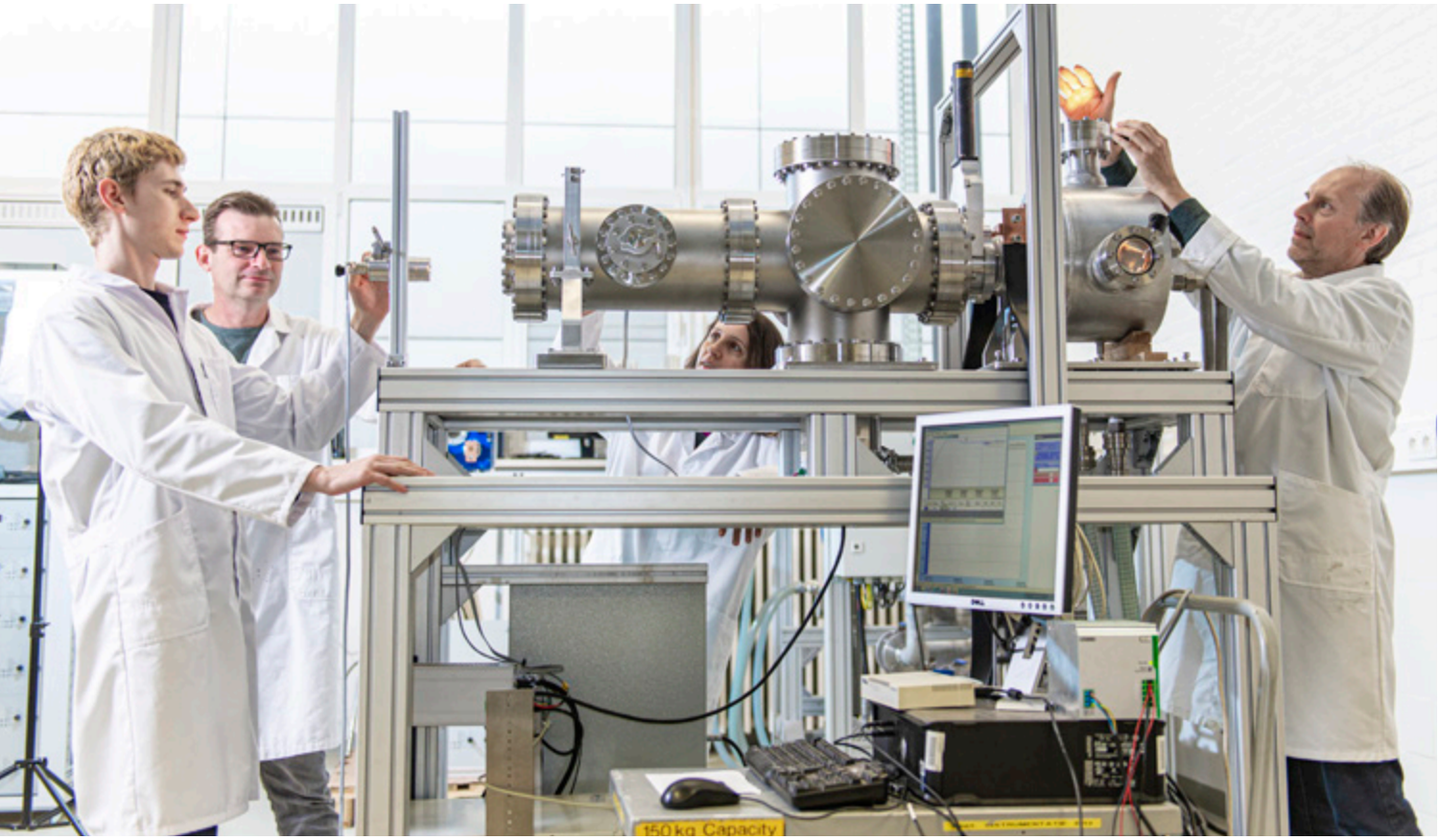
Costs

Full time students pay the enrolment fee at the university where they register for the programme.
The fee of part time students (being those spreading the programme over more than one year) depends on the credits they register for at the university.

For continuous professional development programmes, please contact the secretariat.

Communication

Most correspondence concerning the programme goes through the BNEN secretariat (bnen@sckcen.be). However we would also like to ask our students to check their e-mail account of the university on a regular basis.



BNEN MASTER THESIS – PROJECT WORK/INTERNSHIP

General

- The master thesis is an essential part of the post-graduate ('Master after Master') programme for Master of Science in Nuclear Engineering.
- The master thesis is rated about 33% of the student's workload or about 13 to 14 weeks of effective load.
- Students are reminded to have regular contacts, not only with their mentor, but also with their academic promoter, all along the thesis project.
- For more details consult the thesis guidelines in the restricted area of the BNEN website.

Proposing a thesis subject

- By mid-November, students have to submit to the Teaching Committee a thesis proposal, presenting the context, objectives, methodology and expected results of their work, and mentioning a possible academic promoter (if already known) and the mentor(s) proposed.
- Young professionals can propose a subject in their company, provided the work is significantly different from their daily duties and is performed in the perspective of an academic work.
- During the Teaching Committee meeting scheduled mid-November, the proposals are discussed. Complements of information or adaptations may be asked to the students, before accepting the proposal. The Teaching Committee designates for each student the thesis jury, composed of the promoter and (at least) two assessors. A reasonable spread of the thesis jury members over the participating universities is attempted.

Submitting the thesis

- Students are not allowed to defend their master thesis before the promoter has signed the thesis abstract page (see BNEN website, Thesis section). For this purpose, a preliminary version of the thesis must be made available to the promoter, 4 weeks before the presentation at the latest.
- Once the thesis work has been approved for defense by the promoter, a complete paper version of the thesis report must be made available to all jury members 2 weeks before the presentation at the latest.

- The strict respect of these procedure and guidelines conditions the authorization to present the thesis. In case they are not respected, the presentation of the thesis will automatically be postponed to the next session.

Plagiarism

- Plagiarism is the act of using any part (text, graphs, pictures…) of a written document authored by a third party (of even one self), without properly referencing it.

- Students guilty of plagiarism in any course report or in the thesis report of their BNEN programme put themselves at the risk of severe penalties, which can range from a nil mark for the concerned course to an adjournment, with explicit mention of "fraud' on the formal records. Electronic checks for plagiarism of all theses are performed by the university administrations.

Prizes on final year thesis (for information only)

- SCK CEN annually allots a prize of € 1000 to the best university thesis carried out in its laboratories. http://www.sckcen.be

- The Belgian Nuclear Society – Young Generation allots prizes of up to more than €1500 to a thesis or paper in the field of nuclear sciences. http://www.bnsorg.be

- The Belgian Physical Society annually awards three scientific prizes, € 250 each, to reward the best master thesis in the field of physics. http://www.belgianphysicalsociety.be

GRANTS

The grants are called BNEN grants, or possibly BNEN-XXXX grant, where XXXX stands for the sponsoring company.

Selection

- Grants are awarded based on a selection made by the BNEN Steering Committee.
- Ranking is according to the best academic results.

Admission criteria

- Enrolment for the interuniversity programme in Nuclear Engineering at a BNEN university (KU Leuven, UCLouvain, UGent, ULiège, VUB, ULB).
- Applicants are available full time for the studies (60 ECTS in one academic year).
- Or at least half time (60 ECTS spread over two academic years), no grant in case of failure for the next year.
- Students with a full-time employment are not eligible for the grant.
- Applications have to be sent to the BNEN administration before August 1.

Application file

An application file consists of, at least:

- A motivated application for a grant
- A curriculum vitae
- Transcripts of academic results
- Evidence of enrolment for the interuniversity programme in Nuclear Engineering
- A declaration on the (non-) employment situation

Grants

- Depending on the BNEN financial reach, up to three BNEN grants a year might be given.
- The gross grant amounts to € 10,000.
- Due to administrative reasons, grant instalment may be rather late in the academic year (the objective: January 15: first payment, April 15: second payment).

Advice

Applicants are advised to consult a BNEN professor at their university as soon as possible.

DELIBERATION RULES

In accordance with Annex 4 to the interuniversity BNEN Agreement N°4 – general rules applied since 2007-2008.

Article 1 (criteria for passing course units)

A student shall be deemed to have succeeded in a course unit if **at least 10 out of 20 points** or a 'pass' assessment has been awarded.
In both cases a **credit certificate** shall be delivered to the student, unless the enrolment fee was not paid on time or fraud has been established.

Article 2 (weighting)

In order to establish the **percentage** obtained for the BNEN year of study, the individual course results are weighted by the number of ECTS characteristic of that course and/or master project work or thesis.
The BNEN Teaching Committee, at its discretion, can decide to adjust or modify the ECTS allocation of the particular courses and master project work or thesis in general, or for individual students in case those students request credit transfer from earlier course work or from exchange courses. If changes have occurred compared to the previous year, the new arrangement shall be made public at the start of the academic year.
The course units that are only assessed by means of the 'pass/no pass' system are excluded from the calculation of the (weighted or unweighted) percentage.

Article 3 (criteria for succeeding the BNEN year of study)

All courses are graded with marks out of 20; i.e., each result is expressed as x/20 with
0. le. x .le. 20. A grade less than 10/20 is referred to as a 'failing grade'.

Definition:
For each failing grade for a course, the number of 'fail points' is defined as the number of points below 10/20. E.g., a score of 08/20 amounts to two 'fail points'.
If applicable, the number of 'fail points' for several courses is added together to obtain the total number of 'fail points'. E.g., a score of 08/20 for one course and 09/20 for another course amounts to three 'fail points'.

A student shall be deemed to have passed the complete BNEN year of study when one of the following two conditions has been met:

a) S/he has passed all courses of the year of study (10/20 or 'pass'); i.e., a **percentage of 50%** suffices if all courses have been passed successfully.

b) In case of course failure (other than the master thesis/project), a maximum of two scores of 09/20 can be 'pardoned' by the Examination Board, on the condition that every 'fail point' is 'overcompensated' by 2 %-pts in the average percentage score. This means that the Examination Board is willing to award the degree even in the following cases:
student has one 09/20 but at least 52 % on average;
student has two 09/20 but at least 54 % on average.

c) In case of course failure (other than the master thesis/project), a maximum of one score of 08/20 can be 'pardoned' by the Examination Board, on the condition that every 'fail point' is 'overcompensated' by 2 %-pts in the average percentage score. This means that the Examination Board is willing to award the degree even in the following case:
student has one 08/20 but at least 54 % on average.

d) As a rule, in case of a total of more than 2 'fail points' (i.e., the accumulation of all marks short of 10), students will not be 'pardoned'.

e) For the master project/thesis a minimum score of 10/20 is always required.

In exceptional circumstances the Examination Board may decide to award a pass to a student who failed to meet the criteria set forth in the present examination regulation. Each member of the Examination Board or the ombudsperson may request a secret vote. If the Examination Board decides (whether by secret vote or not) to award a pass to the student in such a case, it shall justify its decision by citing the special circumstances that prompted the decision.

In the case of students who follow a part-time or personalized itinerary arranged according to a programme of several study years, the Examination Board shall only take a decision on whether a student has passed or succeeded if the latter has obtained results for all the course units of one year of study.

For students not satisfying the requirements to pass as laid down in this Article 3, the decision will be recorded as 'adjourned', except for an incomplete submission as explained in Article 4.

Article 4 (special examination board decisions)

The BNEN examination board may establish that a student:

- is guilty of irregular conduct and decide to impose one of the sanctions as described in the examination regulation of the university of registration.
- has not participated in all exams and has therefore submitted an incomplete result, in which case a decision is made to postpone a final judgement on said student. On the transcript, the decision will be recorded as 'incomplete'.

<u>Article 5</u> (criteria to obtain a Master's degree and levels of achievement)

The student who has passed the BNEN year of study obtains the degree of Master in Nuclear Engineering. Students who have a reduced study load and whose programme of study is divided differently in time, shall obtain the degree of Master when they have passed each of the course units of their programme of study, albeit taking into account the conditions set out in Article 3.

A student obtaining the degree of Master shall be awarded with the following levels of achievement:

- satisfaction (cum fructum), if the student passes according to the rules laid down in Article 3;
- distinction (cum laude), on condition that 68% of the marks have been obtained and that all course units received a mark of at least 10/20;
- great distinction (magna cum laude), on condition that 77% of the marks have been obtained and that all course units received a mark of at least 10/20;
- greatest distinction (summa cum laude), on condition that 86% of the marks have been obtained and that all course units received a mark of at least 10/20;

For each 9/20 or in case of an 8/20; two and four percentage points, respectively, are added to the above mentioned requirements for levels of achievement.

BNEN

Belgian Nuclear higher Education Network

ID Picture

Academic Year 2021-2022

☐ Unique year ☐ Unique year bis ☐ Part I ☐ Part I bis ☐ Part II ☐ Part II bis

Registration form

TO SEND BACK NOT LATER THAN
MARCH 15, 2022 (International students) / June 15, 2022 (Belgian students)
Please complete this form and send it to
Kris Pennemans:
SCK CEN, Boeretang 200, B-2400 Mol,
E-mail: bnen@sckcen.be

APPLICANTS DATA

Private data

Last Name: First Name: ☐ Prof. ☐ Dr. ☐ Mr. ☐ Ms.
Private address:
Zip: Town: Country:
Place of birth: Date of birth: Nationality:
Passportnumber: Date of Issue: Valid till:
National register no.:

Professional data

Company: Address:
Position at company:
Zip: Town: Country:
Phone: Fax: E-mail:

University in which you intend to enroll

☐ KU Leuven ☐ ULB (referent university French-speaking universities) ☐ UGent ☐ VUB

Please use capitals.

REGISTRATION FORM

Hereby I apply for registration in the BNEN "Belgian Nuclear higher Education Network". I accept that my application is subject of a selection procedure, and may be refused, if the steering committee decides so, due to any reason. I understand that my travels to Mol (Belgium) and back, my accommodation, my insurances, and the acquisition of the necessary visa have to be arranged and paid individually if I will be selected for participation.

The following documents are attached to my application:

1) A Curriculum Vitae (English knowledge must be stated).
2) A list of courses followed during the university studies. A short description of the content of the following courses: mathematics and physics with your corresponding scores.
3) A statement about the way of the coverage of the costs of my participation (own sources, home university, grant, fellowship, etc.).
4) A copy of your degree(s).
5) We advise students to provide us a GRE (Graduate Record Evaluation) score. It will help us to make a decision about your application.
6) Proof of registration at the university

Date: Signature: N/A (electronic)

After signing this document the candidate acknowledges that:

- *After acceptance of the application by the BNEN Steering Committee, the candidate is authorised to enrol at one of the partner universities for the 'Master of Nuclear Engineering' (KU Leuven, UGent, VUB) or for the 'Master Complémentaire en Génie Nucléaire' (UC Louvain, ULiège, ULB).*
- *The acceptance notification only is not sufficient for non-EU candidates to apply for a student visa. Proof of registration in one of the partner universities is needed.*
- *Registration for isolated courses only is not sufficient for non-EU candidates to apply for a student visa.*

Annex

Presentation of BNEN courses

Nuclear energy: introduction

Prof. William D'haeseleer – KU Leuven

3 ECTS 90 hours study time	20 contact hours theory
	15 load hours excersises/laboratory sessions/visits
	5 hours additional personal work (readings etc.)

Learning Outcomes

To place the world and the Belgian nuclear energy production in its economic, social, technical and cultural context
To give a first overview of nuclear electricity generation and an overall introduction to reactor and plant engineering

Content

- Birds-eye view of nuclear power generation: principle of generating electricity by nuclear means (fission; chain reaction; heat transfer to coolant; turbine; alternator); fissile & fertile materials; burn up; production of fission products; breeding; current types of power plants (PWR, BWR,...); future types of power plants (LWR-type, gas cooled, ADS, ...); introduction to the fuel cycle; front end, back end; introduction to safety aspects of nuclear reactors (criticality; core melt); engineered safety systems; risk; difference with research reactors & fusion reactors; interaction ionizing radiation with matter and elementary aspects of radiation protection.
- Economics of nuclear power generation: European Utility Requirements; life time of existing NPP's; cost of nuclear kWh; investment costs of new types NPP's; construction time and licensing process; decommissioning costs; internalisation of waste management; external costs
- Compatibility of nuclear electricity generation with sustainable energy provision
- Situation of nuclear power in Belgium, Europe and worldwide
- Public perception & communication (media, general public, public authorities).

Course material and reference books

Textbook followed:

- John R. Lamarsh & Anthony J. Baratta, “Introduction to Nuclear Engineering”; 3-rd Ed., Prentice Hall, Upper Saddle River, NJ, 2001 (ISBN 0-201-82498-1)

Other interesting books:

- Ronald Allen Knief, “Nuclear Engineering; Theory and Technology of Commercial Nucler Power”; 2-nd Ed., Taylor & Francis, Washington DC, 1992 (ISBN 1-56032-089-3)
- David Bodansky, “Nuclear Energy; Principles, Practices, and Prospects”; 2-nd Ed., Springer, Berlin/New York, 2004 (ISBN 0-387-20778-3)

Pre-assumed knowledge or prerequisites

Students are supposed to have a solid knowledge in basis engineering sciences such as thermodynamics, fluid mechanics, heat transfer, material science etc. (Level of electro-mechanical university graduated engineers is optimal).

Grading and examination

First and second session: oral examination, open book.

Attendance to seminars is compulsory, but the content is not part of the oral exam.

Open book preparation of two or three (generally overview) questions. Students can take notes during the 30 min preparation. Using the just made notes, students will then be interrogated orally to check whether they have thoroughly understood the study material. Questions are oriented towards understanding and insight.

Introduction to nuclear physics and measurements

Prof. Nicolas Pauly – Université Libre de Bruxelles

3 ECTS

90 hours study time

24 contact hours theory

9 contact hours excersises/laboratory sessions/visits

0 additional hours personal work

Learning Outcomes

- To understand the basic properties of a nucleus
- To analyze the role of conservation laws in decay processes and reactions
- To understand the principles of neutron physics related to nuclear fission reactions.
- To describe interactions of radiation with matter
- To describe characteristics of main particle detectors

Content

- Nuclear physics (10h)
    - Nuclear properties (nuclear radius; mass and abundance of nuclides; nuclear binding energy; nuclear exited states)
    - Elementary introduction to nuclear models (drop & shell)
    - Radioactive decay: radioactive decay law, radioactive mother-daughter chains, natural radioactive chains, types of radioactive decay, units of radioactivity
    - Alpha, Beta and Gamma decay
    - Types of nuclear reactions: compound nucleus, threshold reactions, concept of cross section
- Interactions of particles with matter (4h)
- Nuclear detectors (8h)
- Accelerators (2h)

Course material and reference books

The PowerPoint presentations of the lectures are available on the BNEN website.

Other useful references:

- Krane, K.S. “Introductory Nuclear Physics”, Wiley, 1987.
- Tavernier, S. “Experimental techniques in nuclear and particle physics”, Springer-Verlag, 2010.
- Knoll, G.F. “Radiation detection and measurement”, 4 ed., Wiley, 2010.

Pre-assumed knowledge or prerequisites

Bachelor level lectures on physics, mechanics, and mathematics.

Grading and examination

- First and second session: written examination (closed book).
- Laboratory sessions are compulsory and count for 20% of the global mark (report + attendance). Laboratory sessions cannot be repeated in the second session.

Nuclear materials

Prof. Marc Scibetta – Université de Liège
Prof. Eric van Walle – KU Leuven
Prof. Rik-Wouter Bosch - KU Leuven

3 ECTS

90 hours study time

24 contact hours theory

10 contact hours exercises/laboratory sessions/visits

3 hours additional personal work (readings etc.)

Learning Outcomes

- To assess the basic aspects of material science as they apply to nuclear systems.
- To review the basic processes of material degradation and ageing due to the nuclear environment (radiation effects, corrosion and fatigue).

Content

- Part 1: Material sciences: Properties of materials in relation with their processing, micro-structure and intended performance (M. Scibetta – 1 ECTS)
    - Atoms and their interactions
    - Crystal structure and imperfections
    - Phase diagram and kinetics effects
    - Material properties (excluding radiation effect and corrosion)

- Part 2: Corrosion phenomena: (R.W. Bosch – 1 ECTS)
    - Description and occurrence
    - Electrochemical and chemical study of corrosion problems: basic equations, user diagrams and practical examples
    - Detailed study of frequently occurring corrosion types (for example pitting, IGA, SCC, ...): setting and context, explanation, influences of the environment and material properties
    - Methods of corrosion prevention and protection (design aspects, coatings, water treatment and inhibitors, electrochemical methods)
    - Effects of radiation on corrosion (for example irradiation assisted corrosion)

- Part 3: Radiation damage and Reactor Pressure Vessel (E. van Walle – 1 ECTS)
    - Radiation effects: introduction and general principles
    - Reactor Pressure Vessel Degradation Mechanisms: part 1

Visit and laboratory session to the SCK CEN research infrastructure

- Laboratory session on mechanical testing: cold lab and hot-cells (M. Scibetta)

Course material and reference books

The PowerPoint presentations of the lectures are available on the BNEN website.

Other useful references:

- Murty, K L., and Indrajit Charit. An introduction to nuclear materials : fundamentals and applications. Weinheim, Germany: Wiley-VCH, 2013
- Konings, Rudy J., et al. Comprehensive nuclear materials. Amsterdam: Elsevier, 2012.
- Glasstone, S. & A. Sesonske, Nuclear Reactor Engineering, 4-th Ed, Vol 1, Chapman & Hall, New York, 1994 (Chapter 7: Reactor Materials, pp 406-462)
- William D. Callister, Jr., David G. Rethwisch Materials Science and Engineering: An Introduction, 9th Edition, Wiley, [2014]
- Furio Ercolessi ; A Molecular Dynamics Primer [1997] http://www.cems.uvm.edu/~gmirchan/classes/EE274/Images/Articles/MD%20Primer.pdf
- T. L. Anderson Fracture Mechanics: Fundamentals and Applications, Fourth Edition, CRC, [2017]

Pre-assumed knowledge or prerequisites

Courses in the following field

- Nuclear energy: introduction
- Introduction to nuclear physics and measurements

Basic chemistry, material behaviour.

Grading and examination

- Part 1, 2 & 3: Oral examination with written preparation, open book
- The laboratory session on mechanical testing are compulsory and cannot be repeated in second session.
- Report on the laboratory session on mechanical testing (10%).
- The grade will be determined by weighing the grades on the separate parts, in proportion to the number of ECTS per part. In case of a failure for one of the parts, the examination committee can decide to penalize by lowering the final grade.
- The separate parts of the examination can be scheduled on multiple days.

Nuclear fuel cycle

Prof. Christophe Bruggeman – Université de Liège
Prof. Hubert Druenne – Université de Liège

3 ECTS 90 hours study time	26,5 contact hours theory
	7 contact hours excersises/laboratory sessions/visits
	0 hours additional personal work (readings etc.)

Learning Outcomes

To get an overall view of the fuel cycle, from cradle to grave:

- The front-end of the fuel cycle: ore extraction, conversion and enrichment, fuel fabrication and use in the power plant, spent fuel reprocessing and recycling of re-enriched reprocessed U and Pu as MOX in PWR.
- The back-end of the fuel cycle: the radioactive waste management, ranging from waste characteristics, waste treatment technologies, disposal technologies, safety assessment of geologic disposal.

Content

First part – The front-end of the fuel cycle (H. Druenne)

- Description of main U minerals and deposits, and of exploration, ore extraction and treatment techniques
- Conversion of concentrated ores and U enrichment: basic principles of isotopic separation, theory of the cascade (symmetrical cascade) and description of the main techniques (gas diffusion, ulra-centrifugation, LASER and others).
- Choice of the materials, description of the various current commercial core designs and fuel types, and fabrication process.
- Isotopic evolution under irradiation, residual heat and source term.
- Reprocessing of UO2 fuel elements: description of the PUREX process
- Recycling of U and Pu: technology and industrial limits, equivalence principle
- Interim storage : description of the main concepts for dry and wet storage

Second part – The back-end of the fuel cycle (C. Bruggeman)

- Categories, inventory of radioactive waste
- Conditioning and immobilisation of radioactive waste
- Characterization of radioactive waste (general; scaling factors; destructive analysis); chemical durability of immobilized radioactive waste
- Introduction into radiochemistry (fundamentals; techniques used for radioactive tracers and sources)
- Assessment of the safety of geological disposal (methodology; some typical results from the safety assessment)
- Impact of new fuel cycles on radioactive waste disposal
- Geological repositories: key criteria for designing a disposal concept, overview of ongoing international programmes, and discussion of the Belgian supercontainer concept.
- Technical visits to the Belgoprocess facility and to the ESV underground research laboratory in clay on the SCK CEN site

Course material and reference books

The PowerPoint presentations of the lectures and review papers are available on the BNEN website.

Pre-assumed knowledge or prerequisites

Courses in the following field

- Nuclear energy: introduction
- Introduction to nuclear physics and measurements

Basic chemistry, material sciences, nuclear physics

Grading and examination

- First and second session: Oral examination for each part (weighting factor 50%-50%); written preparation, closed book. In case of a failure for one of the two parts, the examination committee can decide to penalize by lowering the final grade.
- Technical visits are compulsory and cannot be repeated in the second session (no report required).
- The examination of the two parts of this course can take place on two separate days.

Radiation protection

Prof. Klaus Bacher – Universiteit Gent

3 ECTS

90 hours study time

24 contact hours theory

3 contact hours laboratory sessions
6 contact hours exercises

0 hours additional personal work (readings etc.)

Learning Outcomes

The aim of the course is:

- to know the basic quantities and units used in radiation protection
- to learn how to apply the concepts of external/internal radiation dosimetry
- to introduce the student to the biologic effects of ionising radiation
- to be able to calculate the effects of shielding materials
- to know the concepts and legislation of radiation protection

Content

1: Radiological quantities and units

- 1.1: Exposure and kerma
- 1.2: Absorbed dose
- 1.3: Equivalent dose
- 1.4: Effective dose
- 1.5: Operational dose quantities

2: External dosimetry

- 2.1 : Ionometry of low energy photon fields
- 2.2 : High energy photon fields: the Bragg Gray relation
- 2.3 : Dosimetry of neutron fields
- 2.4 : Directly ionizing radiation: electrons and charged particles

3: Internal dosimetry

- 3.1 : Concept of committed dose equivalent
- 3.2 : Concept of specific effective energy
- 3.3 : Compartmental model analysis
- 3.4 : Dosimetric model for the respiratory system
- 3.5 : Dosimetric model for the gastrointestinal tract
- 3.6 : Dosimetric model for bone
- 3.7 : Metabolic data of important fission products and actinides

4: Biological effects of ionizing radiation

4.1 : Deterministic and stochastic effects

4.2 : Overview of direct effects including utero

4.3 : Overview of late effects: the UNSCEAR report

4.4 : Biological effect models used in radiation protection

5: Introduction to radiation shielding

5.1 : Build up factors

5.2 : Shielding of photon fields

5.3 : Shielding of combined neutron-photon fields

6: Legislation and regulations

6.1 : The ICRP 103 publication

6.2 : The conceptual framework of radiological protection

6.3 : The system of protection in occupational and public exposures

6.4 : The system of protection in interventions, accidents and emergencies

7: Measurement techniques in radiation protection

7.1 : Ionometry

7.2 : Film dosimetry

7.3 : TLD dosimetry

7.4 : OSL dosimetry

Laboratory sessions (at SCK CEN):

- Internal dose calculations
- ALARA calculations

Course material and reference books

The PowerPoint presentations of the lectures, and extensive lecture notes, are available on the BNEN website.

Other useful references:

- Herman Cember, Thomas Edward Johnson, "Introduction to health physics",
- The McGraw-Hill Companies, 2008
- ICRP, "Publication 30: Limits for Intakes of Radionuclides by Workers", Ann. ICRP 1980
- ICRP, "Publication 103: Recommendations of the ICRP", Ann. ICRP 2008
- N.M. Schaeffer, "Reactor Shielding for Nuclear Engineering", Atomic Energy Commission, USA, 1973
- A.E. Profio, "Radiation Shielding and Dosimetry", Wiley, NY, 1979

Pre-assumed knowledge or prerequisites

- Interaction of radiation with matter
- Measurement techniques

Grading and examination

Written examination accounts for 80% in the total mark:

- exercise part: "open book" (50%),
- theoretical part: "closed book" (50%).

Laboratory sessions are compulsory. Report of laboratory sessions account for 20% in the total mark. Laboratory sessions cannot be repeated in second session.

Nuclear thermal hydraulics

Prof. Yann Bartosiewicz – Université Catholique de Louvain

3 ECTS 90 hours study time	30 contact hours theory
	24 contact hours excersises/laboratory sessions/visits
	14 hours additional personal work (readings etc.)

Learning Outcomes

- To learn how to estimate the volumetric heat generation rate in fission reactor cores under normal operation and shutdown conditions
- To learn how to analyse the thermal performance of nuclear fuel elements
- To learn the basic fluid mechanics of single phase reactor cooling systems
- To learn to calculate pressure drop in reactor systems, including tube bundles, and spacer grids
- To learn to analyse the heat transfer characteristics of single phase reactor cooling systems
- To learn the basic fluid mechanics of two-phase systems, including modelling approaches, flow regime maps, void-quality relations, and pressure drop evaluation
- To learn the fundamentals of boiling heat transfer, and its implications for reactor design
- To calculate and analyze the coolant conditions throughout a reactor loop including the determination of natural convection regime
- To learn the fundamentals of core thermal design, e.g. flow rate/pressure drop relation under different conditions (friction dominated/gravity dominated) for the evaluation of cooling performances

In addition of supervised exercises, a mini-project is organized about modelling and computing pressure drop in a boiling channel (different conditions and assumptions may be treated over the years).

Content

- Thermal design principles/reactor heat generation
- Reminders about single phase transport equations (prerequisite)
- Two-phase flow models, transport equations
- Thermodynamic (vessels/pressurizer) and power conversion cycle (steam)
- Heat transfer analysis in a fuel element
- Reminders about single phase fluid mechanics and heat transfer (prerequisite)

- Two-phase fluid mechanics and pressure drops
- Two-phase heat transfer (pool boiling, flow boiling)
- Single heated channel (thermal and flow problems)
- Flow loops (steady state natural convection)

Course material and reference books

The PowerPoint presentations of the lectures, and additional lecture notes, are available on the BNEN website.

Other useful references:

- Todreas, N.E. and Kazimi, M.S. Nuclear System I: Thermal Hydraulic Fundamentals, Taylor & Francis, Boca Raton, 2012.

Pre-assumed knowledge or prerequisites

A relevant course about introduction to nuclear energy
Fundamentals of fluid mechanics, heat transfer, thermodynamics

Grading and examination

The final mark is composed of (i) a written exam (80%, closed book) including an exercise and a theoretical part, and (ii) evaluation of a mini-project (20%).

Nuclear reactor theory

Prof. William D'haeseleer – KU Leuven
Prof. Jean-Marie Noterdaeme – Universiteit Gent
Prof. Peter Baeten – Vrije Universiteit Brussel

3 ECTS

90 hours study time

44 contact hours theory

24 contact hours excersises/laboratory sessions/visits

12 hours additional personal work (readings etc.)

Learning Outcomes

- To understand the physical processes involved in a nuclear reactor
- To understand and be able to write down and solve the basic equations
- To be able to simulate a reactor/source configuration as appropriate depending on:
    - number of dimensions;
    - steady state or transient;
    - number of groups;
    - delayed neutron precursors;
    - space dependent properties.
- To learn how to measure neutron distributions and parameters relevant for nuclear reactors, in particular reactivity and reactivity coefficients

Content

- Physics of nuclear reactors
- Transport theory
- Diffusion theory
- Spatial dependence
- Slowing down theory
- Cell calculations
- Neutron thermalisation
- Multigroup equations
- Point kinetic equations
- Reactor dynamics including reactivity effects
- Experimental reactor physics

Lab session with static and kinetic measurements at the BR1, Sigma pile and VENUS facility

Course material and reference books

The PowerPoint presentations of the lectures, and extensive lecture notes, are available on the BNEN website.

Other useful references:

- J.J. Duderstadt and L.J. Hamilton, "Nuclear Reactor Analysis", 1976 (Wiley & Sons)
- Lamarsh, J.R., "Introduction to Nuclear Reactor Theory", Addison-Wesley, Reading, Mass., 1966
- Profio, A.E., Experimental Reactor Physics, J. Wiley, 1976
- P. Reuss, "Neutron physics", 2008 (EDP Sciences)

Pre-assumed knowledge or prerequisites

- Introduction to nuclear physics
- Introduction to nuclear engineering

Grading and examination

Written examination, open book. The course contains three parts, each part is individually evaluated on the exam. The final mark will be calculated based on a weighted average on the three parts. (weighting factor roughly 1/3, 1/3, 1/3). In case of a failure for one of the parts, the examination committee can decide to penalize by lowering the final grade.

Laboratory sessions are compulsory and cannot be repeated in the second session. No report is required, but questions on the laboratory session might be included in the exam.

Safety of nuclear power plants

Prof. Hubert Druenne – Universiteit Gent
Prof. Pierre- Etienne Labeau – Université Libre de Bruxelles

3 ECTS

90 hours study time

42 contact hours theory

6 contact hours exercises/laboratory sessions/visits
4 hours seminar

0 hours additional personal work (readings etc.)

Learning Outcomes

To introduce the students to methods and practices supporting the defense-in-depth approach for nuclear power plants.

More specifically:

- To present elements of nuclear safety philosophy.
- To understand how to ensure the link between nuclear safety and reactor operation.
- To master all the contributors to the core reactivity balance and power distribution in normal operation.
- To understand specific measurement and control issues in nuclear reactors.
- To introduce the basic notions and techniques of system reliability engineering.
- To understand the concepts of safety analyses (both deterministic and probabilistic), and the fundamentals of probabilistic safety analysis (PSA).
- To present some PSA-based applications.

Contents

Operation & Control (28h)

- Cycle specific safety evaluation methodology.
- Basic principles of the in-core fuel management based on the linear reactivity model.
- Reactivity coefficients (moderator, Doppler), neutron poisons (xenon, samarium, ...), their variation with burnup and core state parameters and their impact on core power distribution.
- Reactivity control means (boron, control rods, burnable poisons) and their sensitivity to the core burnup and in-core fuel management parameters.
- Operating modes, operating limits and protection diagram.
- Fuel rod design and thermal-mechanical behavior in normal operation and accidental conditions.
- Thermal-design procedures and elaboration of the core thermal limits and core protections.
- Core control, surveillance and protection systems

Optional visits and laboratory session:

- Visit of a Nuclear Power Plant.
- Two day session of compact and full scope Nuclear Power Plant simulator.

Reliability & Safety (14h theory + 6h exercises)

- Introduction to nuclear safety and defence in depth
- concept of risk, individual and societal risk criteria, release limits, core damage frequency limit, safety goals at function or system level
- deterministic vs. probabilistic safety analyses;
- probabilistic safety assessment (PSA) methodology and PSA levels
- Component reliability
- Fault tree and event tree analysis
- Markov analysis
- Common cause failure analysis
- Elements of human reliability analysis
- Elements of the level 2 and level 3 PSA methodology
- Limits of the classical PSA methodology
- PSA-based applications

Seminar: description of nuclear accidents (TMI, Chernobyl, Fukushima-Daiichi…)

Course material and reference books

Operation & Control

- Collection Génie Atomique "La chaudière des réacteurs à eau sous pression Ed. EDP Sciences, 2004
- Collection Génie Atomique « Exploitation des cœurs REP », Ed. EDP Sciences, 2008
- USNRC Technical Training Center, « Pressurized Water Reactor Systems"

Reliability & Safety

- McCormick, N., Reliability and Risk Analysis – Methods and Nuclear Power Applications, Academic Press, New York, 1981.
- Henley, E.J. and Kumamoto, H., Reliability Engineering and Risk Analysis, Prentice Hall, Englewood Cliffs, 1981.
- Modarres, M., What Every Engineer Should Know about Reliability and Risk Analysis, Dekker Inc., New York, 1993.
- Kumamoto, H., and Henley, E.J., Probabilistic Risk Assessment and Management for Engineers and Scientists, 2nd Edition, John Wiley & Sons, New York, 2001.
- Bedford, T. and Cooke, R., Probabilistic Risk Analysis, Foundations and Methods, Cambridge University Press, New York, 2001.

Pre-assumed knowledge or prerequisites

Courses in the following field

- Nuclear reactor theory
- Nuclear thermal hydraulics

Grading and examination

Operation & Control

First and second session: Individual oral exam, closed book, written preparation

Reliability & Safety

First and second session: Written examination (closed book).

- The grade will be determined by weighing the grades on the separate parts, in proportion to the number of ECTS per part. In case of a failure for one of the parts, the examination committee can decide to penalize by lowering the final grade.
- The examination of the separate parts of this course can be scheduled on multiple days.

Advanced nuclear reactor physics and technology

Prof. Hamid Aït Abderrahim – Université Catholique de Louvain-la-Neuve

3 ECTS

90 hours study time

24 contact hours theory

8 contact hours excersises/laboratory sessions/visits

0 hours additional personal work (readings etc.)

Learning Outcomes

- Describe the specifics of the different reactor codes
- Master the adjoint theory for neutron transport
- Describe the 6 GEN IV designs accepted by the GIF
- Give an overview on the on-going developments for Gen IV systems and perspective of deployment
- Compare GEN IV with GEN II and GEN III reactors.
- Give specific attention to the Accelerator Driven System and its role in closing the fuel cycle
- Give an overview of international networks and research infrastructures for GEN IV systems

Content

Theoretical part

- Reactor codes and adjoint theory – 4h
- Reactor Physics for fast reactors – 4h
- GEN IV reactor technologies – 6h
- ADS reactor physics and technology – 6h
- GEN IV and the closed fuel cycle – 4h

Laboratory session and exercises

- Laboratory session – GUINEVERE – 4h
- Exercise session on reactor codes & criticality accidents– 4h

Course material and reference books

The PowerPoint presentations of the lectures are available on the BNEN website.

- Introduction to Nuclear Engineering – John R. Lamarsh – Third Edition
- Reference Book for Accelerator Driven Systems will be provided

Other useful references:

/

Pre-assumed knowledge or prerequisites

Courses in the following fields

- Nuclear reactor theory
- Introduction to nuclear physics and measurements
- Nuclear fuel cycle

Grading and examination

First and second session: written examination on theory and exercises (open book).

Advanced nuclear materials

Prof. Marc Scibetta – Université de Liège
Prof. Eric van Walle – KU Leuven
Prof. Rik-Wouter Bosch - KU Leuven

3 ECTS
90 hours study time

26 contact hours theory/seminars

5 contact hours exercises/laboratory sessions/visits

0 hours additional personal work (readings etc.)

Learning Outcomes

To review the corrosion and embrittlement degradation mechanisms of materials in nuclear environments.

Content

- Part 1: Functional requirements of materials in a nuclear environment (M. Scibetta – 1 ECTS)
    - Nuclear materials: fuel, fuel cladding, moderator/reflector, coolant
    - Structural materials: reactor internals and vessel, piping, valves

- Part 2: Corrosion and materials degradation problems in the nuclear industry (R.W. Bosch – 1 ECTS)
    - Material behaviour and material requirements
    - Technological aspects and environment-sensitive damage, with emphasis on light water reactors in general and steam generators in particular
    - Nuclear waste treatment: corrosion effects on storage and disposal
    - Advanced reactor systems (GEN IV)

- Part 3: Advanced treatment of irradiation effects in materials: radiation damage mechanisms at microscopic level (E. van Walle – 1 ECTS)

Some of these topics are further elaborated during seminars by SCK CEN experts

- Corrosion in nuclear systems - general overview (R-W. Bosch)
- Fundamentals of radiation damage in steels: the nanoscale perspective (L. Malerba)
- Materials issues of nuclear fuel (M. Verwerft)
- Advanced experiments to characterize radiation damage in nuclear materials (M. Konstantinovic)

Course material and reference books

The PowerPoint presentations of the lectures are available on the BNEN website.

Other useful references:

- Fontana, M.G., Corrosion Engineering, 3rd Ed., McGraw-Hill, 1986.
- Bogaerts, W.F., Active Library on Corrosion (CD-ROM), 2nd Ed., Elsevier, 1998.
- Benjamin, M., Nuclear Reactor Materials and Applications, Van Nostrand Reinhold, 1983.
- Glasstone, S. & A. Sesonske, Nuclear Reactor Engineering, 4-th Ed, Vol 1, Chapman & Hall, New York, 1994 (Chapter 7: Reactor Materials, pp 406-462).
- Cahn, R.W., Haasen, P., Kramer, E.J., Materials Science and Technology, Volume 10 B, Volume editor Frost B.R.T. , Chapters 7-9

Pre-assumed knowledge or prerequisites

Courses in the following field

- Nuclear materials

Basic knowledge of materials science, chemistry and electrochemistry.

Grading and examination

- Part 1 and part 2: Oral examination with written preparation, closed book in first and second session
- Part 3: Oral examination with written preparation, open book in first and second session
- Attendance to the seminars is compulsory.
- The grade will be determined by weighing the grades on the separate parts, in proportion to the number of ECTS per part. In case of a failure for one of the parts, the examination committee can decide to penalize by lowering the final grade.
- The examination of the separate parts of this course can be scheduled on multiple days.

Advanced Radiation protection/Radiation ecology

Prof. Klaus Bacher – Universiteit Gent

3 ECTS 90 hours study time	20 contact hours theory
	12 contact hours excersises/laboratory sessions/visits
	12 hours additional personal work (readings etc.)

Learning Outcomes

The aim of this course is:
to know the concepts, guidelines and regulations on radiologic protection and to be able to apply them in practical situations
to learn to apply the contemporary risk models for risk calculations of biologic effects
to understand to concepts of Monte Carlo simulations in applications for radiological protection
to know the concepts of atmospheric dispersion calculations for radiological impact assessments
to know the concepts of radiation exposure to the environment and non-human biota

Content

Radiation protection concepts, guidelines and regulations:
- ICRP 103
- International Basic Safety Standards

Risk models for biologic effects of ionizing radiation:
- UNSCEAR, ICRP and BEIR VII data
- Lifetime attributible risk

Monte Carlo model calculations
- Principles of Monte Carlo calculations
- Monte Carlo calculations in internal dosimetry
- Monte Carlo calculations in external dosimetry
- Monte Carlo calculations in shielding calculations

Local atmospheric dispersion calculations for radiological impact assessments (seminars from Dr. Johan Camps, SCK CEN)
- The planetary boundary layer
- Gaussian models for routine releases and for accidental releases

- Parameterization of models, determination of atmospheric stability
- Plume rise, topography
- From atmospheric dispersion results towards radiological assessments

Environmental radiation protection (seminars from Dr. Hildegarde Vandenhove, SCK CEN)

- Assessment of radiation exposure to the environment and non-human biota: global approach
- Overview of methodologies/approaches to derive benchmarks for environmental risk assessment
- Radiation dosimetry methods for non-human biota

Lab sessions

ALARA calculations
Environmental radiation protection: ERICA Tiered impact assessment
Local atmospheric dispersion calculations for radiological impact assessments

Course material and reference books

The PowerPoint presentations of the lectures, and extensive lecture notes, are available on the BNEN website.

Pre-assumed knowledge or prerequisites

Courses in the following field
Radiation protection

Grading and examination

First and second session: oral examination with written preparation, open book – 70%
Laboratory reports - 30%. Laboratory sessions are compulsory and cannot be repeated in the second session.

Advanced courses on the nuclear fuel cycle

Prof. Christophe Bruggeman – Université de Liège
Prof. Hubert Druenne – Université de Liège

3 ECTS

90 hours study time

30 contact hours theory

0 contact hours excersises/lab sessions/visits

0 hours additional personal work (readings etc.)

General

These advanced courses are complementary to the compulsory courses on the Nuclear fuel cycle, and will either deepen certain topics, or treat specific topics of high importance.

Learning Outcomes

MOX and Th fuel
To get a global understanding of the utilization of Pu and Th based fuel in light water reactors:
The challenges of the U-Pu-MOX fuel regarding the fuel fabrication, the core and fuel neutronic aspects and fuel behaviour
The Th-Pu-MOX used in LWR for its breeding capabilities, or more realistically as matrix for Pu utilization.
Radiochemistry and Dismantling
To get an understanding of radiochemistry, as it is a basic discipline to understand the various stages and activities in the nuclear fuel cycle, including the safe disposal of the radioactive waste.
To get acquainted with the principles and practice of dismantling and decommissioning of nuclear materials, as this is becoming an activity of increasing importance in nuclear engineering.

Content

MOX and Th fuel
Overview of Th based fuel: physical properties of Pu and Th, main fuel design options
Pu-MOX fuel fabrication (MIMAS process) and fuel rod thermal-mechanical behaviour under irradiation
Pu-MOX impact on reactivity coefficients and safety issues
Th-MOX impact on reactivity coefficients and overview of the possible safety issues

Radiochemistry

Applied radiochemistry (complementary to the course under "Nuclear Fuel cycle"): chemical process technology: radiochemical separation techniques, radiochemical analysis, production of radionuclides
Radionuclide migration through a clay host rock – geochemistry and underlying phenomena: impact on the Safety Case; geochemistry in Boom Clay; role of organic matter; radionuclide speciation, sorption and transport; modelling.

Dismantling, decommissioning
Introduction: definitions, objectives, levels, regulatory aspects, radioprotection, ALARA
Radionuclide inventory, characterization and measurements
Strategy for decontamination of buildings, concrete pieces and structures, metals
Dismantling of a nuclear reactor (the BR3 case): the experience, materials management
Other types of installations to be decommissioned, REX from other projects
Strategies and planning of decommissioning
Safety aspects

The courses will be complemented with exercises.

Course material and reference books

The powerpoint presentations are available on the BNEN website.

Pre-assumed knowledge or prerequisites

Courses in the following field
Nuclear energy: introduction
Nuclear fuel cycle (compulsory courses)

Grading and examination

MOX and Th fuel
First and second session: closed book written examination (MCQ complemented by open justification)
Radiochemistry and Dismantling
First and second session: closed book oral examination; written preparation.

The grade will be determined by weighing the grades on the two parts, in proportion to the number of ECTS per part. In case of a failure for one of the two parts, the examination committee can decide to penalize by lowering the final grade.
The examination of the two parts of this course can take place on two separate days.

Nuclear and radiological risk governance

Prof. Fernand Vermeersch – Université Catholique de Louvain
Prof. Greet Maenhout – Universiteit Gent

3 ECTS

90 hours study time

18 contact hours theory

18 contact hours exercises/laboratory sessions/visits

0 hours additional personal work (readings etc.)

Learning Outcomes

Part 1: Nuclear & Radiological Risk Governance – a critical exploration of theory and practice. Gaston Meskens (SCK CEN)

The student should gain insight into the various theoretical understandings of risk governance as a policy process and be able to assess current practices (nuclear energy policy, climate change policy, policy wrt medical applications, ...) against these theoretical views. In particular, the student should develop an understanding of the working of science in the context of risk governance and be able to develop an own critical opinion with respect to the political and ethical aspects of practices of nuclear & radiological risk governance. In addition, the student should be able to undertake critical readings of existing regulation and recommendations with regard to radiological protection and safety culture (historical development, political dimensions, considerations on accountability, ...).

Part 2: Safety Culture. Fernand Vermeersch (UCL)

The student should be aware of the organisational, the human and the technical dimensions of safety. The student should be familiar with the cultural aspects of safety. The student should be capable to assess some safety culture characteristics and factors. The student should understand the importance of an adequate integrated management system and the concept of processes.

Part 3: Nuclear Safeguards & Security. Greet Maenhout (UGent)

The student should understand the difference in content, legal background and technical implementation of safety, safeguards and security. The student should be able to derive the appropriate statistical test for the 3 safeguards goals. The student should be able to identify proliferation sensitive technologies, how these are dealt with in international trade. The student should be aware of nuclear security measures and detection techniques used at border control.

Content

Part 1: Nuclear & Radiological Risk Governance – a critical exploration of theory and practice.
Gaston Meskens (SCK CEN)

The overall aim of this part is to provide better insight into the complexity of nuclear risk governance and to discuss as well the moral foundations for risk governance as the practical implications for research and policy. The course will start with basic reflections on risk perception and risk justification and will also discuss specific case studies in this respect. Based on these considerations, together with the students, a normative view on the 'method of risk justification and governance' in societal context (as compared to the occupational context) will be constructed. Consequently, this 'normative view on method' will be used to asses current understandings of radiological protection and safety culture (as outlined in existing recommendations and regulations). A last part will concentrate on existing and emerging advanced scientific methods ('technology assessment', 'science & technology studies', 'mode-2 science', 'transdisciplinarity', ...) that would support a more deliberate dealing with risk governance in research and policy.

Part 2: Safety Culture.
Fernand Vermeersch (UCL)

The course shall include a synthesis of the safety culture and integrated management systems points of view of the IAEA. Particular attention will be given to safety culture assessment, its pitfalls and its use in daily practice (case discussions). To anticipate the third part on Safeguards and Security, some discussion about the cultural aspects of safety and security will be presented. The organisational aspects of safety management as part of the management of the entire company within an integrated management system will be presented.

Part 3: Nuclear Safeguards & Security.
Greet Janssens-Maenhout (UGent)

The legal background and the technical measures, necessary to guarantee peaceful use of nuclear energy are explained with a historical overview. The international and regional framework for inspectorates, their goals and detection tools are described, firstly for safeguards of nuclear material and secondly for non-proliferation of nuclear technology. The latter touches upon the Nuclear Suppliers Group and export control with dual-use list and trigger list. Nuclear security will be addressed with examples of detectors and radiation portal monitors used at border control.

Course material and reference books

Part 1: Lecture slides + a reader with key scientific papers
Part 2: Slides of the lectures
Part 3: Nuclear Safeguards and Non-Proliferation (2008), ed. G. Janssens-Maenhout, syllabus of the ESARDA course, ISBN-10: 3844363300 + lecture presentations.

Other useful references:

- For safety culture: Michel Llory, René Montmayeul, 'L'accident et l'organisation', Ed. Préventique, Bordeaux, 2010; ISBN 978-2-911221-47-8 IISN 1275-7144
- IAEA documents: Safety Series INSAG 4 – 15; IAEA TECDOC 1329; IAEA General Standard GS-R-3; GS-G-3.1; GS-G-3.5
- Material available via the TRASNUSAFE project.
- References within the Course of Nuclear Safeguards and Non Proliferation – ESARDA course syllabus.

Pre-assumed knowledge or prerequisites

Part 1: basic knowledge of radiation and nuclear installations, basic knowledge of the nuclear history and of the current state of affairs in nuclear R&D, industry and policy
Part 2: basic knowledge of radiation and nuclear installations
Part 3: Introduction to nuclear energy

Grading and examination

Part 1: oral examination on 20 points
Part 2: oral examination on 20 points
Part 3: Written examination, on 20 points, 12 points for theory, 8 points for exercise.

- The grade will be determined by weighing the grades on the separate parts, in proportion to the number of ECTS per part. In case of a failure for one of the parts, the examination committee can decide to penalize by lowering the final grade.
- The examination of the separate parts of this course can be scheduled on multiple days.

Advanced course elective topic

Prof. Peter Baeten – Vrije Universiteit Brussel

3 ECTS 90 hours study time	16 contact hours theory
	0 contact hours excersises/laboratory sessions/visits
	40 hours additional personal work (readings etc.)

Learning Outcomes

The advanced courses are an essential part of the post-graduate programme for Master of Science in Nuclear Engineering, as they address specialized topics corresponding either to extensions of the contents of regular courses or to practical domains of nuclear engineering.

Content

- At the beginning of the academic year the Teaching Committee offers a menu of advanced courses.
- The student communicates his/her choice of two one-day seminars to Prof. P. Baeten and the BNEN secretariat before October 15.
- Students may submit to the Teaching Committee motivated proposals to follow advanced courses, not appearing in the menu offered. A course should be accessible to all BNEN students, differ significantly from the professional activity of the concerned students (if applicable) and present an academic added value to be eligible. If such a proposal is accepted, students will provide the course material in electronic format to the academic responsible.

Course material and reference books

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Pre-assumed knowledge or prerequisites

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Grading and examination

- Within 3 weeks after the event, students prepare a one-page note presenting a scientific/technical topic related to one of the seminars, which they want to present/discuss, and the main lines of the treatment they plan to develop. This treatment should be mainly based on a personal research, beyond the contents of the course material and of the seminars.
- Comments on this note are sent by the academic responsible within a few days.
- By the next 3 weeks, a 15 page report developing the topic selected by the student must be sent to Prof. Baeten (pbaeten@sckcen.be) and the BNEN secretariat (bnen@sckcen.be). The respect of this deadline influences the mark received by the students.
- Reports should display a clear structure (clear introduction and conclusion, references cited in the body of the text). A mark of 00 out of 20 will be given to reports presenting evidences of plagiarism.

NOTES