Master of Science in Computational Mechanics

Module Handbook

Universitat Politècnica de Catalunya/CIMNE (UPC/CIMNE)
Swansea University (SU)
École Centrale de Nantes (ECN)
Universität Stuttgart (US)

1. WELCOME

Welcome to the Masters in Computational Mechanics. This is an innovative programme designed to promote student mobility within Masters Programmes.

You will spend your first and second semesters in UPC/CIMNE (Spain) or Swansea (SU, UK) before moving to Nantes (ECN, France), Stuttgart (US, Germany), UPC/CIMNE (Spain) or Swansea (SU, UK) for your third and fourth semesters.

The purpose of this handbook is to explain how the Masters in Computational Mechanics will work, and what you can expect from it. The information is intended to help you find your feet and settle into postgraduate life as quickly as possible. The handbook outlines what you can expect at each stage of your studies, the resources available, the structure and staffing at each Institution where you will be studying, and procedures for dealing with any problems you may encounter.

Please read this handbook carefully as it is in your interest to familiarise yourself with the regulations and procedures.

Students who are uncertain about the information in this handbook should ask their course coordinator or contact any of the departmental offices. We hope you will find your time as a member of the postgraduate community at each institution a rewarding and enjoyable experience.

2. DISCLAIMER

The Consortium has made all reasonable efforts to ensure that the information contained within this publication is accurate and up-to-date when published but can accept no responsibility for any errors or omissions.

The Consortium reserves the right to revise, alter or discontinue modules and to amend regulations and procedures at any time, but every effort will be made to notify interested parties.

It should be noted that not every module listed in this handbook may be available every year, and changes may be made to the details of the modules.

3. BEING A STUDENT ON THE MASTERS PROGRAMME

Key Dates

Dates of Semesters:

Year 1

Semesters 1 and 2:	UPC/CIMNE:	01 October 2018 – 30 June 2019
	Swansea University:	01 October 2018 – 30 June 2019

(Exact dates to be confirmed)

Year 2

Semesters 3 and 4:	UPC/CIMNE:	01 October 2019 – 30 June 2020
	Swansea University:	01 October 2019 – 30 June 2020
	Stuttgart University:	01 October 2019 – 30 June 2020
	Ecole Centrale de Nantes:	01 October 2019 – 30 June 2020

(Exact dates to be confirmed)

Enrolment

The enrolment process is a means of recording data on students and for Institutions to provide important information to students. During the enrolment process students also declare that they will abide by the regulations of the universities concerned. Students will enrol at their starting Institution.

Notification of Change of Address

The Consortium needs to be informed of any change of address – whether it is a change in semester-time or home address. Normally students should inform the Scheme coordinator at whichever Institution they are studying. The coordinator will then have the responsibility for informing all other Institutions within the Consortium.

Whilst studying in Barcelona please notify change of address to: Ms. Lelia Zielonka, lelia@cimne.upc.edu

If you study any part of the degree program at Swansea please make sure that any change of address is updated on your University intranet account.

Students studying at Nantes and Stuttgart will be told the procedure for notifying changes of addresses at the start of their study period at Nantes and Stuttgart.

Regulations

By enrolling on this course, students agree to abide by the Academic Regulations and Assessment Regulations included in this handbook. In addition, each institution may have its own general or financial regulations that students will need to adhere to. Information on these will be provided when you commence studies in that Institution.

Attendance and Progress

Students are expected to attend all lectures and examinations scheduled. It is recognised however, that due to illness or exceptional circumstances, this may not be possible in all instances. Students should report absences and reasons for them to the scheme coordinator at whichever Institution they are studying. You may be required to present a medical certificate where this is appropriate.

In addition, students are reminded that they should inform the Scheme Coordinator of any circumstances they feel might adversely affect their performance. Failure to do so will result in you not having legitimate grounds for appeal of assessment decisions. The local coordinator will be responsible for informing the appropriate Examining Board.

General Conduct and Behaviour

Students shall conduct themselves in an orderly manner. Please note that:

- If you wilfully damage University property you must pay for its repair and may be subject to disciplinary action.
- If you attempt to obstruct teaching, study, research or the administration of any Institution within the Consortium you will be liable to disciplinary action.
- Unauthorized absence from any part of your course without proper cause will render you liable to disciplinary action.
- You are under an obligation to inform the Consortium of any criminal conviction prior to and during your period as a student.

Each Institution operates its own disciplinary procedures. Information on these will be provided to students during their induction at that Institution.

Complaints

The Consortium is committed to ensuring a high quality educational experience for its students, supported by appropriate academic, administrative and welfare support services and facilities within each of its Institutions. In order to help us to help you and improve our delivery and support, you are under an obligation to raise and resolve any issues that you may be dissatisfied about at the Institution in which you are studying as soon as they arise. Most issues can be resolved quickly. If problems persist issues can be raised with the course coordinator or in Swansea at Student/Staff committees. In exceptional circumstances students might feel the need to pursue a complaint through the formal complaints procedures. Details of these procedures will be available in the respective Institutions. It would be envisaged that formal complaints will have been resolved before moving on to the next Institution within the Consortium.

Should a student be unable to resolve a complaint to their satisfaction within the Institution concerned, he/she may approach the Board of Studies of the Consortium. An independent member of the Board will be asked to conduct an investigation into the complaint. For further information contact Ms. Lelia Zielonka at lelia@cimne.upc.edu

Extensions to deadlines

Please speak to your personal tutor/advisor or scheme coordinator at whichever Institution you are currently studying for advice if you believe you have extenuating circumstances which might be affecting your studies. Seek advice on whether to apply for an extension to any course assessment deadline or to your overall deadline.

Extending the deadline for individual assessments

The assessment deadlines for each module will be given to you by the module tutor and or the module handbook at the outset of the semester. There should be no excuse therefore for missing these deadlines. In exceptional circumstances due to ill health or exceptional personal reasons you may find that you are unable to meet a deadline. In this case you should contact the relevant professor as soon as you become aware that there is an issue and before the submission date in question. You should state your case in writing and provide appropriate documentary evidence to support your request.

Transcripts and Diploma Supplement

Students will be issued with an academic transcript and a Diploma Supplement at the end of their studies (free of charge). The diploma supplement is a document, which aims to facilitate academic and professional recognition of qualifications across Europe. It provides a description of the nature, level, context, content and status of the studies that were pursued and successfully completed by the individual named.

Graduation

The degree shall be conferred upon successful candidates at an awards ceremony, date and location to be confirmed. The degree certificate(s) to be issued shall include reference to the collaborative nature of the degree and shall include the name of each Institution involved in the teaching. Exit qualifications shall not normally be awarded to candidates at a ceremony, but such awards shall be conferred upon candidates administratively.

4. ORGANISERS

An international Consortium of four leading European Educational and Research Institutions in cooperation with the International Center for Numerical Methods in Engineering (CIMNE). All Institutions of the Consortium have a long standing tradition in the field Computational Mechanics, with the highest standards both in research and teaching.

Universitat Politècnica de Catalunya, UPC (Spain)

http://www.upc.edu/

Swansea University, SU (UK)

http://www.swan.ac.uk

Ecole Centrale Nantes, ECN (France)

http://www.ec-nantes.fr

Universität Stuttgart, US (Germany)

http://www.uni-stuttgart.de

CIMNE is an autonomous international research organization specialized in the development and application of numerical methods in engineering.

http://www.cimne.com

Practical information about the organizing Institutions is included in section 12, at the end of this handbook

5. PRESENTATION

The Master of Science in Computational Mechanics is designed for students who wish to develop their knowledge and competency in the field of computational mechanics with applications in solids, fluids and interdisciplinary fields. The goal is to provide the students with the skills for the modelling, formulation, analysis and implementation of simulation tools for advanced engineering problems, as well as skills for understanding these approaches in the broader context of engineering science. Students will benefit from a consortium of leading academics and an exciting international environment. Students may take the Masters as a professional terminal degree, or in preparation for a PhD. degree.

The programme lasts two academic courses (120 ECTS) and includes a Master Thesis as well as Practical Training in an industrial or applied research environment. The first and second semester are aimed at providing a solid background on computational mechanics and numerical methods as well as entrepreneurship awareness, transversal skills and practical industrial training. Students can select to follow the first and second semesters either at UPC or SU. The third and fourth semesters are designed as a minor in order to gain a deeper knowledge in a particular area within computational mechanics and must be pursued in an institution different to the institution where they stayed for the first two semesters.

The **first semester** consists of a set of core modules (20 ECTS) complemented by transversal modules (10 ECTS) including a module in entrepreneurship skills. The core modules are taught jointly at UPC and SU.

The **second semester** consists of a set of elective modules (15 ECTS) complemented by a practical training module (15 ECTS) at industry or an applied research centre.

The **third and fourth semesters** (60 ECTS) consists of a minor aimed at providing a deeper knowledge in a selected area by means of a set of elective modules (25 ECTS) and transversal modules (5 ECTS). The third and fourth semesters must be followed in a second institution different from the selected for the first semester. The Master thesis is supervised and developed in the second institution during the third and fourth semesters.

6. ADMISSIONS

Admission Requirements

A candidate must hold a Bachelor of Science or Engineering, or an appropriate science degree deemed to be a satisfactory standard for the purpose of postgraduate admission (at least 180 ECTS) and awarded by an Institution recognized by one of the members of the Consortium. Applications must include a statement of purpose (one/two pages), a CV, complete academic transcripts and three letters of recommendation. A score of at least 6.5 IELTS (or equivalent TOEFL or TOEIC) is required for students from non-English speaking countries.

Application Process (via web) http://www.cimne.com/cdl

For further questions please contact the masters Secretariat science@cimne.upc.edu

Visas and Residence Permits

Students are responsible for securing their own visa, if a visa is needed. However, all consortia partners will assist you in applying for a visa if required. Visa regulations can be very strict. Students are advised to abide by the regulations very carefully to prevent a delay in your application.

It is important that you:

- Check if all the forms are filled in completely,
- Send all the required documents within the time fixed,
- Make copies of the original documents. When original documents are required, keep a copy for your own records. If possible, save a digital copy of all important documents.

You are strongly advised to apply for the visa for both countries that you are intending to study in before you leave your home country. If this is not possible you should be able to apply for the visa for the second country that you will be studying in after you arrive on the course. However, please ensure you bring all of the necessary documentation with you and you will need to be prepared to travel to Madrid/ London to make the application.

Tuition Fees

The fees for the duration of the course will be €8000 for European Union students (that is students from the twenty-eight Member States in the European Union) and €16,000 for other students. CIMNE will collect fees in four instalments at the start of each semester.

Recall that member states are currently: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom.

Please note that a limited amount of bursaries may be available to offset the difference in fees between European and non-European fees for those students who are not already in receipt of an stipend for the scheme. For further information contact Ms. Lelia Zielonka at lelia@cimne.upc.edu

Financial Support

A limited number of grants offering total or partial support to cover the course tuition fees are available. Further information will be posted at the Masters web page www.cimne.com/cm-master.

7. MOBILITY AND LANGUAGE POLICY

English is the language of instruction and examination throughout the programme. Before being admitted to the course non-native English speaking students must demonstrate high levels in both written and spoken English, with an IELTS minimum score of 6.5 or equivalently internationally accredited qualification. All theses must be written in English and any public defence must also be conducted in English.

Students study in two of the consortium institutions. They meet all together in Barcelona at the beginning of the second academic year in order to interact, meet each other and exchange impressions regarding their experience after the first academic year. They pursue their first and second semesters in the first institution (UPC/CIMNE, SU), which is responsible for teaching 60 ECTS. Their third and fourth semesters (60 ECTS) are conducted in the second Institution (obviously, different from that of their first two semesters), which is any of the four: UPC/CIMNE, SU, ECN, US. Mobility of students is restricted to the period between the second and third semesters and, those that decide to complete their Master Thesis in China, have an extra mobility in the middle of the second year.

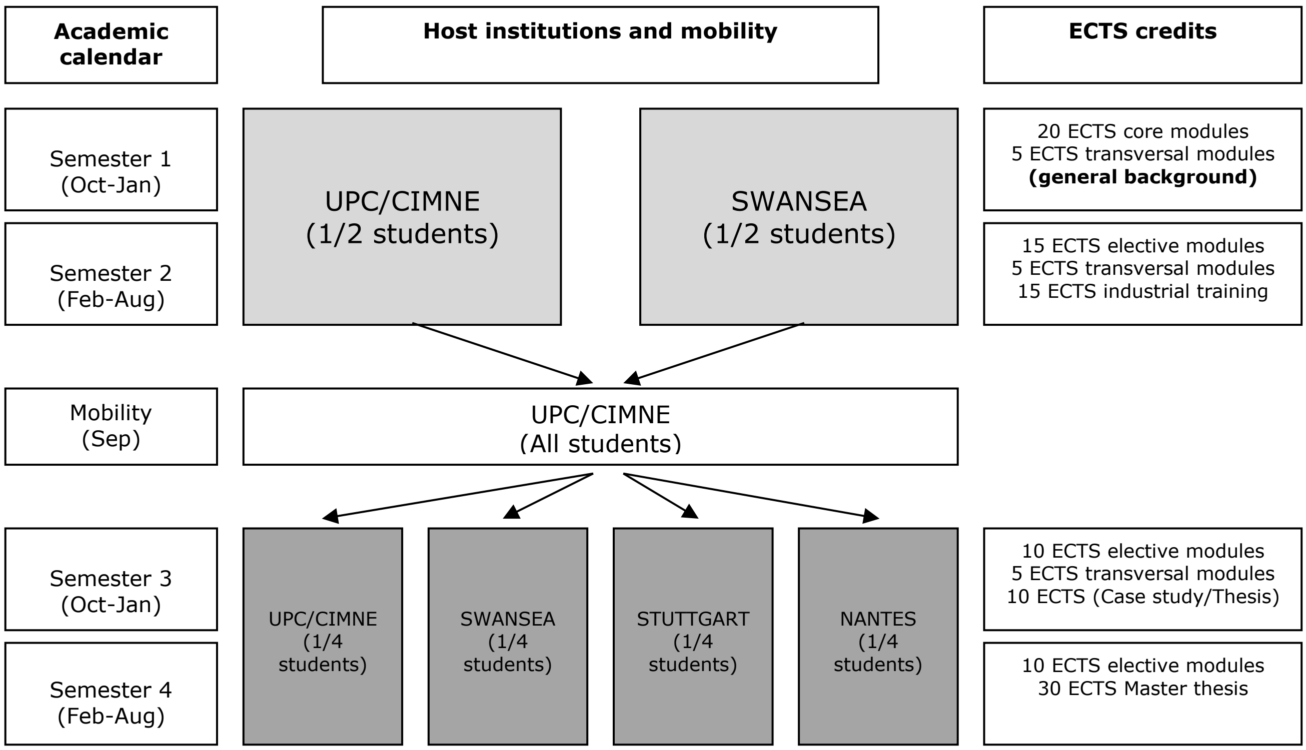
The choice of Institution depends mostly on the student's preferences and also on an even distribution of students among the Institutions. Students select their preferences on the admission form. The Board of Studies at its winter meeting decides both if a student is admitted and his/her corresponding mobility. This decision is communicated to the student before the registration period.

All partner Institutions have wide-ranging experience with international exchanges and have well-developed logistical systems to coordinate the welcome and assistance of international exchange students. At each partner Institution international offices, in cooperation with the local academic host (viz. department, institute, etc.), will coordinate the logistics including housing facilities, visas, social security and other relevant information before arrival.

The International Offices provide support during the stay, with dedicated staff offering supervision and advice.

8. PROGRESSION AND AWARD REGULATIONS (ASSESSMENT RULES)

1. STRUCTURE OF SCHEME



The scheme consists of two parts: **Year 1** (first and second semesters) provides basic background in computational mechanics as well as a practical training component. **Year 2** (third and fourth semesters) includes a series of specialised modules into a particular field of computational mechanics and a research/directed independent learning component.

The first semester is taught simultaneously in UPC/CIMNE and Swansea University. Students study commonly agreed core modules, totalling 20 ECTS, which are examined under common regulatory procedures. In addition, students study 10 ECTS in transversal modules, namely a course in "communication skills in a foreign language" and a course in "entrepreneurship for engineers". Students must accumulate 30 ECTS by passing each module at 50 or above to progress.

Students continue in UPC/CIMNE or Swansea University for their second semester, where they must accumulate new 30 ECTS. Students study 15 ECTS in elective modules in computational mechanics to deepen the knowledge acquired during the first semester. Students must also accumulate 15 ECTS in a "practical training" module which they will develop within an industrially oriented environment. Students must accumulate 30 ECTS by passing each module at 50 or above to progress

The third and fourth semesters are taught at a second designated institution from within the Consortium (from a choice of UPC/CIMNE, SU, US and ECN). Students must accumulate 60 ECTS (25 ECTS of which should be in specialised subject areas) and 5 ECTS will be in the form of a transversal module. The final 30 ECTS consists of a Masters directed independent learning thesis into a cutting-edge research topic within computational mechanics.

Progression Boards will be held at the end of every semester to determine the academic progression of the students to the subsequent semester.

2. GENERAL PRINCIPLES

2.1 Institutions shall inform students, by means of handbooks and module literature, the means by which modules shall be assessed and the method of reassessment for redeeming a failure.

2.2 All formal written examinations sat at the Partner Institutions shall, so far as national practice allows it, be marked in the anonymous state. This means that Candidates in such examinations shall be identified only by their student number until such time as both first and double marking have been completed.

2.3 Partner Institutions shall so far as possible, and in keeping with national practice, mark other forms of assessment in the anonymous state also. It is, however, recognised that feedback from certain elements of assessment form an integral part of the learning experience and that, for practical reasons, it might not be possible to follow the policy at all times. Methods of assessment, which involve observation, interaction and oral/aural elements, and in particular the Year 2 element of the degree, shall not be subject to anonymity.

2.4 Progression/ Examining Boards shall be presented with all marks of assessment undertaken during the Semester(s) concerned. Marks for modules of the scheme shall be recorded out of a hundred according to the marking criteria in 3 below.

2.5 Resit marks must be clearly identified in the presentation of marks to the Progression/ Examining Board.

2.6 All results will be disclosed to students electronically by CIMNE after the formal Progression/Award Boards.

2.7 To ensure consistency of marking within the Consortium a sample selection of examinations and course work will be double/ second mark. I.e. a member of staff from another Institution within the Consortium or an external examiner, employed by the Consortium to ensure consistency of marking, will second mark a sample of work to ensure overall standards.

2.8 The Consortium will employ an external examiner i.e. a member of staff external to any of the Institutions involved in the Consortium to review the scheme and ensure parity of marking and overall quality of the programme.

3. MARKING CRITERIA

Due to the Collaborative nature of the scheme, the Consortium is committed to the ECTS grading structure. Examinations and assessment will be marked out of a hundred. The marks equate to ECTS grades as follows:

Mark	100 – 90	89 – 80	79 – 70	69 – 60	59 – 50	49 or less
ECTS	A/A+	B	C	D	E	F/FX
Descriptor	**Excellent** Outstanding performance with only minor errors	**Very Good** Above average standard but with some errors	**Good** Generally sound work with a number of notable errors	**Satisfactory** Fair but with significant shortcomings	**Sufficient** Performance meets the minimum criteria	**Fail** Some/ Considerable work required before the credit can be awarded

4. MODULE RULES

4.1 Modules shall be assessed individually, as prescribed by the relevant Institution(s). The assessment method of a module may take the form of an unseen written examination paper, set projects or other course work assignments, but must be appropriate to assess whether a student has met the learning outcomes of the module. A student may also be required to demonstrate to the appropriate examining board, satisfactory completion of any period of professional training or practical experience, failure of which may lead to failure of the module, despite a mark of 50 having been gained for the other assessed work.

4.2 In addition to satisfying the assessment requirements of a module, each student must satisfy the attendance requirements as stated in the handbook. It is the responsibility of Institutions to monitor satisfactory attendance and assessment in each module. Students who do not satisfy the attendance and assessment requirements of a module will be reported to the appropriate Board in the partner Institution concerned.

4.3 A mark will be assigned to each student, based on his/her performance.

4.4 The Pass mark for modules will be set at 50. Credits will be awarded to candidates who pass a module. All modules pursued must be passed. (However, see 4.5 below).

4.5 The late submission of assessed work shall result in a mark of 0 being awarded and a decision of fail being recorded, unless an extension has been granted prior to the deadline. There are no other penalties.

5. PROGRESSION RULES

Progression from Year 1 to Year 2

5.1 A Progression Board shall be held in Barcelona at the end of the first Year to determine whether or not students qualify to proceed to the second year, to be pursued at another designated Institution within the Consortium.

5.2 Students must accumulate 60 ECTS credits (by passing modules with a mark of 50 or better in each module) to progress to Year 2.

5.3 Students whose performance is deemed, by the Progression Board, to be extremely weak (i.e. who accumulate less than 10 ECTS credits on their first attempt at a Semester) will FAIL to proceed further and will not be given opportunities to redeem their failures.

5.4 Students who fail a module(s), but have accumulated 10 ECTS or more (by passing modules at 50 or above) will fail to progress and shall, at the discretion of the Progression Board, normally be permitted one further attempt prior to the start of the second year to redeem their failure in each such module. (See section 7 regarding the marking policy for redeemed modules).

5.5 Students who are eligible to progress to the next year shall not be allowed to repeat any module for which credit has been awarded in order to improve their performance.

5.6 Students who fail to complete the year have the right of appeal in accordance with the appeals procedure adopted by the Consortium Board of Studies.

5.7 To qualify for an award, students must accumulate credits as follows:
Postgraduate Diploma in Computational Mechanics 60 ECTS credits
Masters Degree in Computational Mechanics 120 ECTS credits

6. UNFAIR PRACTICE

6.1 Students must ensure that they do not engage in any form of unfair practice, whereby they take action which may result in them obtaining for themselves or others, an unpermitted advantage.

6.2 Unfair practice is defined as any act whereby a person may obtain for himself/herself or for another, an unpermitted advantage. This shall apply whether candidates act alone or in conjunction with another/others. An action or actions shall be deemed to fall within this definition whether occurring during, or in relation to, a formal examination, a piece of coursework, or any form of assessment undertaken in pursuit of the MSc in Computational Mechanics.

6.2.1 Examples of unfair practice in examination conditions are as follows:

- introducing into an examination room any unauthorised form of materials such as a book, manuscript, data or loose papers, information obtained via an electronic device such as a programmable calculator, pager, mobile phone, hand held computer or any source of unauthorised information;
- copying from or communicating with any other person in the examination room, except as authorised by an invigilator;
- communicating electronically with any other person;
- impersonating an examination candidate or allowing oneself to be impersonated;
- presenting evidence of special circumstances to examination boards which is false or falsified or which in any way misleads or could mislead examination boards;
- presenting an examination script as your own work when the script includes material produced by unauthorised means. This includes plagiarism.

6.2.2 Examples of unfair practice in non-examination conditions are as follows:

- ***Plagiarism***. Plagiarism can be defined as using without acknowledgment another person's work and submitting it for assessment as though it were one's own work, for instance, through copying or unacknowledged paraphrasing (see 6.2.3 below);
- ***Collusion***. Collusion can be defined as involving two or more students working together, without prior authorisation from the academic member of staff concerned (e.g. Programme leader, lecturer etc) to produce the same or similar piece of work and then attempting to present this work entirely as their own.

Collusion may also involve one student submitting the work of another with the knowledge of the originator.

- Commissioning of work produced by another;
- Falsification of the results of laboratory, field-work or other forms of data collection and analysis.

6.2.3 Examples of plagiarism are as follows:

- use of any quotation(s) from the published or unpublished work of other persons which have not been clearly identified as such by being placed in quotation marks and acknowledged;
- summarising another person's ideas, judgements, figures, software or diagrams without reference to that person in the text and the source in the bibliography;
- use of the services of `ghost writing' agencies in the preparation of assessed work;
- use of unacknowledged material downloaded from the Internet;
- submission of another student's work as your own;

6.3 Students suspected of having engaged in unfair practice or assisting another student to engage in unfair practice, either in coursework or examination will be subject to the unfair practice procedures at the Institution in which they are studying.

6.4 Institutions will investigate any cases of unfair practice identified at their Institution, by means of their usual procedures and inform the Consortium of their results.

6.5 Students accused of engaging in unfair practice will be given an opportunity either in writing or in person to present their case.

6.6 Students found guilty of unfair practice will be subject to the following penalties:

6.6.1 The issue of a written reprimand to the candidate, a record of the reprimand should be kept;

6.6.2 The text to be ignored when marking, resulting in a reduced mark;

6.6.3 The cancellation of the candidate's marks for the assignment;

6.6.4 The cancellation of the candidate's mark in the module concerned;

6.6.5 The cancellation of the candidate's mark in the module concerned and the preclusion of redeeming the failure until the next academic session;

6.6.6 The cancellation of the candidate's marks in all of the modules for the particular level of study;

6.6.7 The cancellation of the candidate's mark in all of the modules for the particular level of study and the disqualification of the candidate from any future Consortium examination;

6.6.8 In the event of an Institution deciding that the above penalties are inappropriate, the Institution may use its discretion to decide upon an appropriate penalty.

6.7 The Institution should consult the student's case history and academic record before imposing a penalty. In order to ensure consistency in the application of penalties, the Consortium will develop a guidance note/ Code of Practice on the normal penalties for Unfair Practice. The normal penalty for unfair practice in non-examination conditions (1st offence) shall be the cancellation of the candidate's mark(s) in the module(s) concerned. However, the Institution may wish to take into consideration the seriousness of the offence and impose a harsher penalty in accordance with the Code of Practice. Alternatively it might take into account mitigating circumstances. The Institution should be convinced that the mitigating circumstances have a direct bearing on the case and, in particular, had influenced the action of the student concerned.

6.8 Students have the right of appeal, against substantiated allegations of Unfair Practice, in accordance with the appeals procedure adopted by the Consortium Board of Studies.

7 REDEEMING A FAILURE

7.1 Students who fail a module in the first or second Semester will fail to progress and shall, at the discretion of the Progression Board, normally be permitted one further attempt before/ shortly after the beginning of the next Semester to redeem their failure in each such module, provided that this can be achieved within the time limit for the degree. The mark for this further attempt shall be up to the capped threshold of 50 in each such module, irrespective of their actual level of performance.

7.2 With regards students who fail a module the Progression Board has the discretion to allow a student to:

- be re-examined in the module as a whole (mark capped at 50, final attempt); or
- be re-examined in those parts of the module which he/she has failed where more than one piece of work contributes towards the final module mark. (mark capped at 50, final attempt)
- be re-examined without any restriction on mark. This would only be allowed where the student has demonstrated special circumstances to the Board. See section 8.

7.3 Students must not expect, as of right that they will be allowed to redeem failures, allowed to repeat failed modules or be allowed to continue. The Progression Board may take into account other circumstances relating to the candidate's case, such as attendance and performance in classes, before taking any progression decision. A Progression Board would not be expected to allow a candidate to progress unless he/she had satisfied the minimum criteria and demonstrated competence to undertake work required at the next stage.

7.4 A candidate who is to be re-examined in set projects or other forms of course assessment shall not be permitted to re-submit modified versions of his/her original work, but shall be required to submit for examination new work on different topics from those, which originally failed to satisfy the examiners.

7.5 Candidates who are attempting to redeem a failure and who fail on the second attempt, will be informed that they have failed the scheme but will be considered for an exit award where appropriate.

7.6 Candidates who pass the failed modules and accumulate at least 30 ECTS credits, at 50 or above, in modules at the appropriate Level qualify to proceed to the next Semester.

7.7 The Consortium reserves the right to charge a re-submission / re-examination fee in respect of failed modules or the re-submission of the directed independent learning.

8 EXCEPTIONAL CIRCUMSTANCES

8.1 A student who is absent for the whole of a written examination (or who fails to submit set projects or coursework by the required date(s)) will be deemed to have failed the modules(s) in question. In the case of illness or other exceptional circumstances, the Progression Board may grant an extension to the submission date or permit a supplementary examination to be held as appropriate. It is recognised that the marks of such students will not be subject to the ceiling of 50. They will be considered as 'First Sit' students, which mean that they will be marked according to the same grading scale as students who attempt the examinations/ course work for the first time. The mark(s) of such candidates shall be considered at the "Supplementary Exam Board".

8.2 Students who attend an examination/ submit coursework as directed but fail a module due to illness or other exceptional circumstances may, at the discretion of the Progression Board, be allowed to sit the examination/submit course work again, as a 'First-sit' candidate. This means that they will be treated in the same way as students who take the examinations/ submit the coursework for the first time and their marks will not be capped (i.e. not subject to a ceiling of 50). The mark(s) of such candidates shall be considered at the "Supplementary Exam Board".

8.3 Students who miss a submission deadline/ are absent from an examination or who fail a piece of coursework or an examination due to illness or other exceptional circumstances should notify the course leader at the Institution in which they are studying before the examination or deadline for submission or if this is not possible as soon after the examination/ deadline as is possible and before the date of the examination board. To be considered as a 'First Sit' candidate the student will need to provide written evidence (for example medical certificates) to the Board.

8.4 In the same way as students who fail modules at the first attempt 'First Sit' candidates who have failed modules shall be allowed to redeem failures at the next available opportunity, usually by resitting them before the start of the next academic year, by:

- being re-examined in the module as a whole (mark capped at 50, final attempt); or
- being re-examined in those parts of the module which he/she has failed (mark capped at 50, final attempt)

8.5 Further information on Swansea University's extenuating circumstances policy can be found at:

https://www.swan.ac.uk/academic-services/academic-guide/assessment-and-progress/extenuating-circumstances-policy/

9 SPECIFIC RULES – YEARS 1 and 2

INDUSTRIAL PROJECT

9.1 Practical training (Industrial project) is an essential element in the curriculum providing inside knowledge in computational mechanics project development and management. Professional or R+D profiles will be provided in industry or in applied research organizations which are in close collaboration with all Institutions in the Consortium. This training can be closely related to the Master thesis.

9.2 The student will be given a nominated contact within the placement generally a line manager. The student will also be assigned a tutor at the Institution.

9.3 The Industrial project is worth 15 ECTS and will last for at least 7 weeks of full-time dedication (or an equivalent period)

9.4 It can take place any time during the second semester, in agreement with the host Institution for this period.

9.5 Due to the nature of the project there will be no mechanism for redeeming a failure should a student fail.

9.6 Students who fail the industrial project, will be informed that they have failed the scheme but will be considered for an exit award where appropriate.

9.7 Students who fail to complete the industrial project have the right of appeal in accordance with the appeals procedure adopted by the Consortium Board of Studies.

Thesis/Directed Independent Learning

General Principles

9.8 A supervisor will be appointed for each candidate who will be responsible for ensuring that studies are carried out in line with the Institution's good practice guidelines.

9.9 Normally, no designated supervisor who has been involved in the preparation of the directed independent learning shall act subsequently as an examiner for it.

9.10 The student should submit three typed copies and one electronic copy of the directed independent learning to the Exam Coordinator, in the format prescribed by the Consortium Board of Studies and notified to the student by the Institution at which the work takes place.

9.11 Directed independent learning submitted for examination shall normally be openly available and subject to no security classification or restriction of access. However Partner Institutions may, place a bar on photocopying of and/or access to the submitted directed independent learning for a specified period of up to five years. It shall be the responsibility of the candidate's project supervisor to make an application to the Consortium Board of Studies and any appropriate body in the partner Institutions as soon as possible and before the result is known. This request will be reported to the Year 2 Award Board.

9.10 A candidate is at liberty to publish the whole or part of the work produced during the candidate's period of enrolment at the Institution, prior to its submission as a whole, or as part of the directed independent learning, provided that in the published work it is nowhere stated that it is in consideration for a higher degree. Such published work may later be incorporated in the directed independent learning submitted for examination.

9.11 Retention and disposal of the directed independent learning shall be in accordance with the policy of the awarding Institution.

Examination

9.12 Due to national differences in the countries making up the Consortium, the marking criteria and assessment rules (for instance the length of the directed independent learning and the requirement to make a public or private defense) for the directed independent learning element of the degree will vary slightly depending on which Institution the student completes his/ her directed independent learning in. Students should familiarise themselves with the regulations of the Institution in which they submit their directed independent learning.

9.13 In all Institutions the directed independent learning will be examined by both an internal examiner (who will not be the student's supervisor) and an external examiner (who may be a member of staff from another Institution within the Consortium). The marking structure followed will be in accordance with national rules and will reflect the marking structure for final award detailed in section 11 below.

9.14 If the directed independent learning is failed by the examiners, the candidate may re-present it once only, not more than three months from the date of the official communication to the candidate of the result. A fee shall be payable to the Institution concerned for the examination of such a re-presented directed independent learning.

9.15 At year 2, a candidate who fails to submit the directed independent learning/project by the deadline specified for the scheme, and who has not been granted an extension of candidature due to special circumstances will fail the degree but might be considered for an exit award.

10 EXTENSIONS OF CANDIDATURE DUE TO SPECIAL CIRCUMSTANCES

10.1 The time limit for the completion of the degree may be extended in exceptional cases only. A reasoned application, supported by appropriate independent evidence, must be submitted by the candidate's tutor for consideration, to the Consortium Board of Studies, and any appropriate Institutional academic committees.

Requests for an extension shall be considered with reference to the following criteria:

(a) Normally, suspensions / extensions will be granted only on compassionate grounds, or in cases of illness, serious domestic difficulties or exceptional commitments, which can be demonstrated to have adversely affected the candidate. A full and reasoned case, supported by appropriate, satisfactory, medical or other independent evidence, and a work-plan for completion of the directed independent learning within the extension requested, must be made by the department for consideration by the Consortium Board of Studies, in the first instance, and thereafter by the appropriate committee of the awarding Institution.

(b) In cases which arise as a result of illness:

- Satisfactory medical or other relevant documentary evidence must be supplied. (The extent and nature of the illness as described in the certificate are invaluable in assessing the case).
- A clear statement must be supplied, showing that the Institution concerned has evaluated the situation in which the candidate finds himself / herself as a result of the illness and that it considers the requested extension to be appropriate for completion in accordance with the work-plan. Such a statement will, wherever possible, follow direct contact between candidate and Institution.

11 FINAL AWARD

11.1 At the end of the fourth Semester, the final Joint Award Board for all students will be held at one of the partner Institutions to determine award decisions on students pursuing all Masters schemes offered by the Consortium. The Board shall be attended by representatives from each Institution and a Senior External Examiner, appointed by the Consortium Board of Studies to be responsible for overseeing the schemes overall. It will be serviced by a senior administrative officer from one of the partner Institutions.

11.2 The students' overall performance on the schemes shall be considered and the remit of the Board will be to:

- Receive notification and formally endorse Year 2 results;
- Receive notification and formally endorse any requests for Bar's on Access;
- To determine the overall award and in particular to consider cases of candidates who might be eligible for the awards of Distinction/ Merit in the UK, Matricula de honor/ sobresaliente in Spain, Très Bien/ Bien in France or 1-1.5 in Germany;
- Consider statistical data on all schemes offered by the Consortium;
- Conduct an annual review of all schemes.

11.3 The full set of results for each candidate considered at a Year 2 Award Board, shall be presented to the examiners. The result profile of the relevant students will include:

- The Year 1 results, also including the Year 1 average and the Year 1 decision;
- The results of the directed independent learning;
- The results of the industrial project;

11.4 Both Parts of the degree must be completed successfully before a candidate may qualify for the award of a degree

11.5 A candidate's Year 1 results may not be subsequently reviewed to determine the outcome for the whole scheme.

11.6 Appeals against award decisions shall be considered in accordance with the appeals procedures adopted by the Consortium's Board of Studies, and administered by the partner Institution concerned in conjunction with their own awarding Institutional regulations.

11.7 Successful students will be awarded a joint Masters degree from both the first and second Institution in which they study, unless the national/ institutional practice in the institution concerned prohibits it, in which case a double Masters degree from both the first and second Institution in which they study will be awarded.

11.8 Degrees will be awarded according to national assessment structures, namely:

United Kingdom	Distinction (Candidates who pass all modules and achieve an overall mark of not less than 70% for the whole scheme, having achieved 65% or more in Year 1 and 70 (UK marking rules– ECTS A/B) in Year 2, shall be eligible for the award of a Masters Degree with Distinction.)		Merit (Candidates who pass all modules and achieve an overall average mark of not less than 60% and not more than 69.99% for the whole scheme, having achieved 57% or more in Year 1 and 60 (UK marking rules– ECTS C/D) in Year 2, shall be eligible for the award of a Masters degree with merit.		Pass	Fail
Spain	Sobresaliente	Notable		Aprobado		Suspenso
France	Très Bien	Bien	Assez bien	Passable		Echoué
Germany	1.0-1.5	1.6-2.5	2.6-3.5	3.6-3.8	3.9-4.0	4.1-5.0

These equate to ECTS descriptors as follows:

ECTS	A/A+	B	C	D	E	F/FX
Descriptor	Excellent (outstanding performance with only minor errors)	Very Good (above average standard but with some errors)	Good (generally sound work with a number of notable errors)	Satisfactory (fair but with significant shortcomings)	Sufficient (performance meets the minimum criteria)	Fail (Some/ Considerable work required before the credit can be awarded)

11.9 In order to be eligible for a Distinction in the UK, students must pass all modules and achieve an overall average mark of not less than 70% for the whole scheme, having achieved 65% or more in Year 1 and 70% or more in Year 2.

11.10 In order to be eligible for a Merit in the UK, students must pass all modules and achieve an overall average mark of not less than 60% and not more than 69.99% for the whole scheme, having achieved 57% or more in Year 1 and 60% or more in Year 2.

12. THE VIRTUAL CENTRE

The Virtual Centre of CIMNE provides a 24 hours 7 days a week forum for communication among students as well as with their teachers, regardless of their geographical location, and administrative staff. The Virtual Centre also hosts web based course content made available to the students for each module. Most of the existing modules have been developed over a number of years in each of the Institutions making up the Consortium and a significant amount of high-quality web based course content is available. The Virtual

Centre also provides mechanisms for disseminating official notices of the Consortium and obtaining student feedback.

The course material includes lecture notes and some textbooks. A collection of examples and exercises will be provided as well as computer codes introducing the students to the finite element method in practical applications.

13. STUDENT SERVICES AND RELEVANT CONTACT INFORMATION

For questions related to the Masters course students should contact:

Masters Secretariat
International Center for Numerical Methods in Engineering (CIMNE)
Edificio C1, Campus Norte UPC, Gran Capitán s/n
08034 Barcelona, Spain
Tel. + 34 -93 401 74 41, Fax + 34 -94 401 65 17
e-mail: science@cimne.upc.edu

For up-to-date information students should check www.cimne.com/cm-master. In addition, other useful links are:

In Barcelona

UPC Institutional and International Relations Office

www.upc.edu/ari/english/home

Barcelona Centre Universitari

http://www.bcu.cesca.es/angles/index.htm

In Swansea

Academic Services (For general student enquiries)

Email: academic.services@swansea.ac.uk or myunihub@swansea.ac.uk Tel: +44 (0) 1792 513546

International Student Advisory Service (ISAS) (for visa advice)

Email: ISAS@swansea.ac.uk Tel: +44 (0) 1792 602000

See http://www.swansea.ac.uk/isas/immigration/ for further information.

Academic Partnerships Office (for advice and information related to joint/ collaborative programmes at Swansea)

Email: AcademicPartnerships@swansea.ac.uk

Tel: +44 (0) 1792 295604

In Nantes

International Relations

Building D, BP 92101, F-44321 Nantes Cedex 3, FRANCE

international@ec-nantes.fr

In Stuttgart

Office of International Affairs

http://www.uni-stuttgart.de/ia/internat/index_eng.html

STRUCTURE OF THE PROGRAMME

The Masters Programme consists of four Semesters. It amounts to 120 ECTS credits and lasts for two academic years. Students attend two Institutions: the first Institution (either Barcelona or Swansea) is responsible for teaching 60 ECTS and the second Institution (Stuttgart, Nantes, UPC/CIMNE or Swansea) the remaining 60 ECTS. The programme aims to provide a theoretical and practical background in a specific field within computational mechanics. A series of transversal skills and entrepreneurship orientated modules are included in order to provide awareness and knowledge into those aspects required to translate concepts of computational mechanics into an industrial environment. The programme concludes with a Masters thesis (30 ECTS) which should help the student to deepen his/her knowledge within a particular topic of computational mechanics, usually set at the frontier of cutting-edge computational mechanics technology. Table 1 displays the general structure of the programme, detailing the number of ECTS (i.e. compulsory, elective, transversal, entrepreneurship) to be taken at the various institutions of the consortium.

<table>
<tr><td colspan="2">PART 1 (30+30 ECTS)
Taught and practice based element</td><td colspan="2">PART 2 (30+30 ECTS)
Minor and research element</td></tr>
<tr><td colspan="2">1st Institution</td><td colspan="2">2nd Institution</td></tr>
<tr><td>First Semester</td><td>Second Semester</td><td colspan="2">Third and Fourth semesters</td></tr>
<tr><td>Core modules
(20 ECTS)</td><td>Elective modules
(15 ECTS)</td><td rowspan="2">Elective modules
(max 10 ECTS)
Case Study
(10 ECTS)
Transversal module
(5 ECTS)</td><td rowspan="2">Elective modules
(complete a total of 15 ECTS)</td></tr>
<tr><td rowspan="2">Language module
(5 ECTS)</td><td rowspan="2">Language and entrepreneurship modules
(5 ECTS)
SUMMER: Industrial placement
(15 ECTS)</td></tr>
<tr><td colspan="2">Masters thesis
(30 ECTS)</td></tr>
</table>

Table 1: Structure of the programme

1. First and second semesters.

The first and second semesters (60 ECTS) are taught at a host institution, which can be either UPC/CIMNE or Swansea University. The first semester (30 ECTS) provides fundamental background in computational mechanics with four core modules amounting to 20 ECTS, as well as transversal modules amounting to 10 ECTS, resulting in a final total of 30 ECTS. As part of the transversal skills modules, students will be exposed to a module in "entrepreneurship for engineers" in order to raise their awareness into those vital aspects required to translate knowledge in computational mechanics into an industrially orientated environment. Students will also enrol on a course on "communication skills in a foreign language" to improve their knowledge of the local language of the country of the second host institution. The first semester is simultaneously taught at UPC/CIMNE and Swansea University, with identical core modules and a unified examination/evaluation procedure.

The second semester (30 ECTS) provides extra background in computational mechanics with a series of courses amounting to 15 ECTS into important aspects of solid and fluid mechanics. The semester ends with a Practical Training (15 ECTS) module, which is an essential element in the curriculum providing students with the opportunity to apply their skills and knowledge in computational mechanics in an industrial context.

Students will be placed in engineering industries, consultancies or research institutions that have an interest and expertise in computational mechanics and will carry out an agreed practical project either during a single continuous placement of seven weeks or via an equivalent series of shorter visits. The nature of the project will very much depend upon the placement but can involve structural mechanics, solid mechanics, fluid mechanics or hydrodynamics. Typically, students will be trained by the relevant industry in the use of their in-house or commercial computational mechanics software. The outcome of this project will be a report and a presentation to be completed at the end of the first academic year. The report and presentation will be assessed by two internal examiners who will also consider a formal written report submitted by the industrial supervisor.

At the end of the module, students should have gained expertise on the application of computational mechanics in an industrial context. The project should allow them to appreciate the practical aspects of computational mechanics and the way in which is being used in industry to solve real engineering problems. Students will gain knowledge and expertise in the use of the particular range of commercial software used in the industry where they are placed. At the end of the module students should be capable of writing a comprehensive technical report on the work developed and present it to a small audience.

1st Semester Swansea University & UPC/CIMNE

(30 ECTS)

Compulsory Modules	**ECTS**
Numerical Methods for Partial Differential Equations	5
Finite Element Method	5
Continuum Mechanics	5
Advanced Fluid Mechanics	5
Transversal modules (compulsory)	**ECTS**
Entrepreneurship for engineers	5
Communication skills in a foreign language	5

2nd Semester Swansea University

(30 ECTS)

Structural Engineering Elective Modules	**ECTS**
Computational Plasticity	5
Nonlinear Continuum Mechanics	5
Fluid Structure Interaction	5
Fluid Mechanics Elective Modules	**ECTS**
Computational Fluid Dynamics	5
Reservoir Modelling and Simulation	5
Computational Electromagnetics	5
Industrial placement (compulsory)	**ECTS**
Practical training	15

2nd Semester UPC/CIMNE

(30 ECTS)

Structural Engineering Elective Modules	**ECTS**
Computational Solid Mechanics	5
Computational Structural Mechanics and Dynamics	5
Fluid Mechanics Elective Modules	**ECTS**
Finite Elements in Fluids	5
Industrial placement (compulsory)	**ECTS**
Practical training	15

2 Third and fourth semesters

The third and fourth semesters are pursued in the second host institution. They are organized into minors, consisting of a set of modules emphasizing, or bearing particular relevance to, a specific area in computational mechanics. Each institution offers two minors (cf. ***Table 2***), the contents of which are adapted to its expertise, and defines the compulsory and elective modules for each minor. While some modules fall strictly within one minor, other modules deal with transversal advanced topics relevant to more than one minor.

The student must choose a partner institution for the second academic year, different from that where he/she conducted the first academic year. In agreement with the local requirements of the second institution, the student must select a set of modules adding up to 25 ECTS, in such a way that at least 15 ECTS qualify for a minor.

The **Masters Thesis** (30 ECTS) can be research or industry oriented. The student carries out the thesis on a topic related to one of his/her areas of specialisation. The Master thesis includes the seminar series in computational mechanics developed in each Institution during the 2nd academic year. These seminars will be compulsory for senior students. The thesis should be submitted by end of the second academic session. Once completed, the Masters thesis will be defended in front of a local committee, with the external assessment of at least one faculty member of another institution of the consortium. The final mark of the thesis will be awarded by the Board of Studies of the Masters programme during its summer meeting.

Institution	First semester (30 ECTS)		Second semester (30 ECTS)		Third and fourth semesters (30 ECTS)						
	Core modules	Transversal and entrepreneurship skills	Elective modules	Industrial Training	Solid Mechanics	Structural Engineering	Fluid Mechanics	Engineering Hydrodynamics	Engineering Materials	Transversa l skills	Masters thesis
UPC/CIMNE	■	■	■	■	■		■			■	■
Swansea University	■	■	■	■		■	■			■	■
ECN						■		■		■	■
University Stuttgart					■				■	■	■

Table 2: Institutions providing each part of the structure of the programme and their corresponding expertise

3rd & 4th Semester Swansea University

(60 ECTS)

Structural Engineering Elective Modules	**ECTS (Term1)**	**ECTS (Term2)**
Dynamics of Structures	5	
Computational Plasticity		5
Advanced Structural Analysis	5	
Nonlinear Continuum Mechanics		5
Fluid Mechanics Elective Modules	**ECTS (Term1)**	**ECTS (Term2)**
Computational Fluid Dynamics		5
Reservoir Modelling and Simulation		5
Fluid Structure Interaction		5
Transversal modules (5 compulsory ECTS)	**ECTS (Term1)**	**ECTS (Term2)**
Communication skills for research engineers	5	
Master Thesis (compulsory)	**ECTS (Term1)**	**ECTS (Term2)**
Case Study(*)	10	
Supervised MSc thesis(*)	15	15

(*) A supervisor will be appointed for each candidate who will be responsible for ensuring that studies are carried out in line with the institution's good practice guidelines. At the end of the semester each candidate must submit his directed independent learning to the exam coordinator in the format prescribed by the consortium Board of Studies. A defence will be organised. The directed independent learning will be examined by both an internal examiner (who will not be the student's supervisor) and an external examiner (who may be a member of staff from another institution within the consortium).

3rd & 4th Semester UPC/CIMNE

(60 ECTS)

Solid Mechanics Elective Modules	**ECTS (Term1)**	**ECTS (Term2)**
Computational Mechanics Tools	5	
Multiscale Computational Mechanics Coupled problems		5
Advanced Discretization Methods	5	
Fluid Mechanics Elective Modules	**ECTS (Term1)**	**ECTS (Term2)**
Computational Wave Propagation		5
Programming for Engineers and Scientists	5	
Transversal modules (5 compulsory ECTS)	**ECTS (Term1)**	**ECTS (Term2)**
Master Thesis (compulsory)	**ECTS (Term1)**	**ECTS (Term2)**
Supervised MSc thesis(*)	15	15

The 4th semester is dedicated to the master thesis. A supervisor will be appointed for each candidate who will be responsible for ensuring that studies are carried out in line with the institution's good practice guidelines. At the end of the semester each candidate must submit his directed independent learning to the exam coordinator in the format prescribed by the consortium Board of Studies. A defence will be organised. The directed independent learning will be examined by both an internal examiner (who will not be the student's supervisor) and an external examiner (who may be a member of staff from another institution within the consortium).

3^{rd} *Semester Modules* Ecole Centrale de Nantes

Students following the 3^{rd} semester in Nantes have to take six compulsory modules for a total of 23 ECTS.
Students have to choose two electives modules for an amount of 7 ECTS, one 4 ECTS module and one 3 ECTS module.

Compulsory Modules: 18 ECTS	Total ECTS
Computational methods for incompressible flows	4
Extended finite element method and level set techniques	3
Model reduction	4
Numerical methods for simulation of coupled problems	4
Physical modeling of fluids	3
Transversal modules: 5 ECTS	
Business Environment	2
French Language	3
Elective Modules (subject to timetable constraints and availability): 7 ECTS	
Computational damage and fracture mechanics for polymers and composites	3
Domain decomposition and iterative solvers	4
Fluid-structure interaction and advanced CFD	3
Materials modeling for numerical simulations	4
Multi-scale numerical methods	3
Numerical methods for uncertainty quantification	4

4^{th} *Semester* Ecole Centrale de Nantes

Master Thesis	30 ECTS

The 4^{th} semester is dedicated to the master thesis. A supervisor will be appointed for each candidate who will be responsible for ensuring that studies are carried out in line with the institution's good practice guidelines. At the end of the semester each candidate must submit his directed independent learning to the exam coordinator in the format prescribed by the consortium Board of Studies. A defence will be organised. The directed independent learning will be examined by both an internal examiner (who will not be the student's supervisor) and an external examiner (who may be a member of staff from another institution within the consortium).

Elective modules	Total ECTS	Solid Mechanics ECTS	Eng. Materials ECTS
Advanced Computational Mechanics of Structures*	6	6	-
Boundary Elements Methods in Statics and Dynamics*	6	6	-
Engineering Materials: Metals#	3	-	3
Engineering Materials: Concrete#	3	-	3
Engineering Materials: Soils#	3	-	3
Foundations of Single and Multiphase Continua	6	4	2
Micromechanics of Materials and Homogenization Methods	6	2	4
Software Development and Numerical Programming	6	3	3
Adaptive Materials and Smart Structures	3	1	2
Theory and Numerics of Materials at Large Strains	6	2	4
Numerical Methods for Differential Equations	6	3	3

* Mandatory Modules for the Solids and Structures minor.

\# Mandatory Modules for the Engineering Materials minor.

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	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
First academic year					Application deadline		Acceptance letter			Registration period			
	Enrollment at 1st institution	**First semester (30 ECTS)**				**Second semester (30 ECTS)**							
		First semester modules (30 ECTS)				Second semester modules (15 ECTS)							
					First semester exams				Second semester exams				
										Industrial training placement (15 ECTS)			Mobility
						Winter Board of Studies							Summer Board of Studies
Second academic year	Enrollment at 2nd institution	**Third and fourth semesters (60 ECTS)**											
		Third semester modules (15 ECTS)				Fourth semester modules (15 ECTS)							
					Third semester exams				Fourth semester exams				
		Research towards Masters Thesis (30 ECTS)										Masters Thesis defence	
						Winter Board of Studies							Summer Board of Studies

Table 3: Student academic calendar

14. PRACTICALITIES

INFORMATION ON UNIVERSITÄT STUTTGART

The Universität Stuttgart, founded in 1829, has integrated the social sciences and the humanities with engineering to become an internationally well known future-orientated place of research and study. Today the university is made up of 140 institutes in 14 faculties, with 5.000 employees and approximately 18.000 students of which around 4.000 are international students.

The Universität Stuttgart holds a leading position in both basic and applied research and is proud of its tradition of close co-operation with industry as well as with other research Institutions such as the Frauenhofer-Society for Production Engineering, the Baden-Württemberg Testing Center, and the German Aerospace Research Institute. These close relationships also stimulate important impulses for teaching at the university.

The Faculty of Civil - and Environmental Engineering consists of 36 professors, 125 teaching and research assistants and 1500 students in 16 institutes.

The university is now also offering various new degree courses, which have come about as a reaction to the continuously changing needs of the global job market as well as the results of globalization in education.
The University is made up of two main campuses, i.e. the Vaihingen-Campus and the Stadtmitte-Campus

The Vaihingen-Campus is located in the suburb of Vaihingen and hosts the faculties of Civil- and Environmental Engineering, Geography, Geology, Biology, Chemistry, Electrical Engineering, Energy Engineering, Manufacturing, Aerospace Engineering, Mathematics, Physics; the offices of other international MSc programmes like MIP, WAREM, INFOTECH, PHYSICS, WASTE, GEOENGINE and COMMAS.

The Stadtmitte campus is located downtown Stuttgart and hosts the faculties of Architecture, Geography, Geology, and Biology, History, Social Sciences, Business, Philosophy, Electrical Engineering, Civil Engineering and Surveying, Energy Engineering, Manufacturing; and the administration of the Universität Stuttgart.

The two campuses are connected via S-Bahn (subway) S1, S2, and S3. To get to the Vaihingen Campus from downtown, take S1, S2 or S3 in the direction of Herrenberg, Flughafen, Vaihingen, or B\"oblingen and get off at Universität. To return downtown (Stadtmitte), take any of the trains (S1, S2, S3) going in the direction of Hauptbahnhof.

There are extensive libraries on both campuses. Also, each campus has its own food court, store, bank, travel agency, copy shop, etc. The food court not only serves as a place to obtain cheap, subsidized food, but is also a place to obtain information on housing, culture, etc.

VISUM

Obtaining a student visa for Germany usually requires at least two months. Therefore, apply for a student visa immediately upon arriving in Swansea or Barcelona and getting the Letter of Admission. The administration in Swansea and Barcelona will help you to arrange a date. The visa should be valid from January 2008. Do not enter Germany with a tourist visa, since a tourist visa cannot be transferred to a student visa once you have entered Germany.

The German Missions Abroad (www.auswaertiges amt.de/www/en/adressen_html)

In your application, please refer to COMMAS, Program and include a copy of your acceptance letter. If your visa application is delayed, contact the COMMAS office for assistance.

If the Embassy/Consulate requires that you open a bank account in Germany, please get in contact with a German bank for further information. (Please note, these banks are listed only as examples, we leave the final choice up to you!)

Commerzbank(www.commerzbank.com)
Deutsche Bank(www.deutsche-bank.de)
Dresdner Bank(www.dresdner-bank.de)
LBBW Bank (has an on-campus office)
(www.lbbw.de/lbbw/html.nsf/webdokumente/start_english.htm)
Postbank(www.postbank.de)
Volksbank(www.vr-networld.de)

INFORMATION ON BARCELONA

UPC's syllabuses are designed so as to address the educational needs of society. By adapting them to the changes taking place at the University and in society, they are submitted to a continuous process of revision and improvement. The syllabuses are divided into curricular areas and the first of these areas corresponds to the selection phase.

The selection phase is designed to evaluate students' ability to make satisfactory progress in the subjects they choose and to finish them in the length of time foreseen; for this reason, it includes both basic course materials and technological subjects specific to the qualification. Not all of the qualifications establish the selection phase at the same point during the course. There are one- and two-semester selection phases. Students must pass the selection phase in no longer than double the amount of time allotted to it: if the selection phase is one semester long, then the student must obtain a pass grade in a maximum of two semesters' time. This time limit does not apply to people who wish to work whilst undertaking their studies. In this case, they can request to take the selection phase under special conditions.

Most UPC Schools are located within the city of Barcelona. Its excellent location in terms of international communications, its Mediterranean climate and its cosmopolitan character are some of the characteristics which make of Barcelona a privileged city.

Barcelona has more than 2000 years of history. The history of its expansion from ancient times is marked on the walls of its buildings and streets. Its entire history is reflected in the present. The location and beauty of Barcelona go hand in hand with the warmth of its residents. Its tradition initiative, hard work and creativity are a result of the continuous influx of different peoples and cultures, which are fundamental to any hospitable and welcoming city. These factors have had an undeniable influence on the vitality of the population and its rich cultural and artistic history.

La Rambla is the main thoroughfare of Barcelona, as well as the city's most famous street. Roman walls can still be seen in the city centre. A good way to acquaint oneself with the city is to walk down La Rambla towards the port. Along this route, visitors come across the impressive old town, with its palaces, churches, museums, squares, small peaceful corners and medieval alleys where Romanesque and Gothic styles coexist. The walls reveal Barcelona's history and the avenue presents us with the city's character.

The markets and bazaars give a touch of colour to the place and testify to its trading tradition. During the long summer months, the old town becomes a light-hearted, open-air celebration.

La Rambla ends at the sea. Restoration projects carried out in this area have rehabilitated Barcelona's sea front. Currently, the city has long beaches, new ports built for leisure, and extensive and beautiful open spaces in which to enjoy a pleasant moment. Continuing along the sea front towards the North, we discover the newest part of Barcelona: the Olympic Village, with buildings designed by reputable contemporary architects and modern street furniture. This is truly a unique area, and a good place to enjoy a walk by the sea front. In a matter of seconds we have gone from the oldest to the newest area of Barcelona.

To speak of Barcelona is to speak architecture, design, painting, festivals, museums, theatre, music, etc. The generations of artists and intellectuals who chose the city as a meeting point and source of inspiration have irrevocably marked Barcelona. Here we can find masterpieces by the main Modernista architects, Gaudí and Puig i Cadafalch: Parc Güell, La Pedrera, Palau de la Música, etc. The city's prized possessions include the Modernista paintings of Rusiñol and Casas, the Miró and Tàpies Foundations, the MACBA (Barcelona Museum of Contemporary Art) and the unique Romanesque art collections which can be found in the National Art Museum of Catalonia. Local theatre is rich, both in tradition and in renovation. During the summer, Barcelona becomes the Mediterranean capital of theatre and music thanks to the international GREC festival, which includes a variety of outdoor performances. During the rest of the year, other cultural and international festivals take place.

Additional information on Barcelona

More detailed information on Barcelona can be found at the following internet address: www.bcn.es

There are several tourism offices in Barcelona. Here are some of them:

Barcelona Information and Tourism Centre
Plaza Catalunya, 17 (metro)
Telephone: 34 906 301 282

Barcelona Information Center
La Rambla, 58
Telephone: 34 933 179 829

Sants Tourism Office

Estación ferroviaria de Sants
Telephone: 34 906 301 282

Barcelona's Area of Influence

Barcelona's area of influence extends to a network of cities surrounding Barcelona and includes the city itself. This extensive metropolitan area is currently home to three million residents.

The future of this urban system is a topic currently being considered by experts at UPC, who are investigating sustainable development proposals. An increasing number of people are moving to different municipalities in Barcelona's area of influence to live, work or study. This is true for 45% of Catalonia's population.

Some of UPC's major campuses and schools are situated in cities located within Barcelona's area of influence:Terrassa, Sant Cugat, Castelldefels and Vilanova i la Geltrú.

All these have good transport links with the city of Barcelona. Travelling to Barcelona from Terrassa, Castelldefels, Sant Cugat and Vilanova takes only 30 minutes by metro or train and is permanently guaranteed. The Manresa campus is located a bit further away. None the less, 26 trains per day connect Manresa to Barcelona in only 70 minutes.

Although they are near Barcelona, these cities each have their own personality and have much to offer.

Climate

Barcelona enjoys a Mediterranean climate, in which extreme temperatures are rare. The Universities of Barcelona have an agreement with Barcelona Housing Service for Students, a specialist organisation in youth accommodation, for the purpose of finding accommodation.

Students are advised to contact Barcelona Housing Service for Students either via Internet, e-mail or fax in order to determine the most suitable type of accommodation available (shared flat, rented apartment or university residence hall), well in advance of their moving to Barcelona.

The staff at Barcelona Housing Service for Students will inform you of the different costs involved in each option. If you do this, you will be able to go straight to your chosen place of residence upon arrival in Barcelona.

RECEPTION OFFICE

The Reception Office provides information and practical orientation to foreign students. All students, when they arrive at UPC, should go straight to the Reception Office in order to start the Technical University of Catalonia (UPC) registration process.

Reception Office staff will inform foreign students about the registration process, language courses, medical insurance and the different services offered by the University. They will also show them how to get to the school where they will be studying.

Reception Offices:

Oficina de Mobilitat Internacional de Barcelona
(International Mobility Office)
C/Jordi Girona, 1-3, mòdul A4
08034 Barcelona
Campus Nord
Tel:+34-93 401 69 37
Fax:+34-93 401 74 02
oficina.mobilitat.internacional@upc.edu

INFORMATION ON SWANSEA

THE CITY

Cosmopolitan, convenient, contemporary- Swansea is a modern city with a maritime feel. Living here brings you all the benefits of living in a city, and the benefits of living by the sea.

From the Maritime Quarter with its beautiful marina scenery, exhibitions, places to eat and the beach beyond; to the town centre with its shops, multi-screen cinema featuring the latest film releases, bowling centre, museum, the Glynn Vivian Art Gallery and the Grand Theatre which presents live performances all year round and is one of Britain's finest regional theatres; there is always plenty to do.

At night, the city comes to life with its wide choice of clubs, bars and restaurants, many situated in the vibrant Wind Street, and the nearby village of Mumbles with its famous pub mile!

What makes the city of Swansea so easy is its manageable size. Nothing is too far away from the centre. Regular buses run to and from the city centre and good coach, rail and motorway connections provide excellent links to many other cities in the UK.

For further information on the city of Swansea see http://www.swansea.gov.uk/

THE UNIVERSITY

Founded by industry in 1920 Swansea University (SU) delivers world impacting research, and is ranked 22nd in the UK (REF 2014.) SU is a vibrant, research-led university at the forefront of academic and scientific discovery, which is based across 2 campus, Singleton, which is set within historic parkland overlooking Swansea Bay and the brand new Bay Innovation and Science campus, on the eastern approach to the City which opened in September 2015.

SU is a thriving academic community with over 15000 students, undertaking more than 500 undergraduate and 130 postgraduate courses. As a result the University provides world-leading research, innovation and educational in an enviable working and learning environment.

Mission Statement

True to the vision of its industrial founders in1920 Swansea University will:

- *Provide an environment of research excellence, with research that is world-leading, globally collaborative and internationally recognised;*
- *Deliver an outstanding student experience, with research-led and practice-driven teaching of the highest quality that produces global graduates educated and equipped for distinguished personal and professional achievement;*
- *Use its research strength, collaboration with industry and global reach, to drive economic growth, foster prosperity, enrich the community and cultural life of Wales and, contribute to the health, leisure and wellbeing of its citizens.*

The Bay Campus

The College of Engineering has moved, along with the School of Management, to Swansea University's brand new Bay Campus, after 95 years delivering degrees on the Singleton Park Campus.

The move establishes Swansea as a dual campus university with all other subjects and the main organisational hub remaining on Singleton Campus.

The Bay Campus is situated in an outstanding location on the eastern approach into Swansea, with direct access onto the beach and its own seafront promenade.

The Bay Campus includes an extensive Engineering Quarter, designed to capitalise on Swansea's research expertise and collaboration with major companies, including Rolls-Royce and Tata Steel.

For more information on the bay campus and the specific facilities there please view http://www.swansea.ac.uk/engineering/bay-campus/

Academic Services

Email: academic.services@swansea.ac.uk

Academic Services is responsible for the areas of academic administration for taught programmes and postgraduate research, collaborative provision, discipline, examinations, graduation, regulations and quality, as well as being home to the University's Welsh Translation Unit. Headed by the Director of Academic Services, Adrian Novis, it has a dedicated Student Liaison section and reception where students and staff can obtain advice or gain access to a number of services, including printing and dissertation/thesis binding.

In addition, any queries that might result in having to change your personal or academic details may have to be referred to Academic Services. For further information on what the Department offers see http://www.swansea.ac.uk/academic-services/

Accommodation

Swansea has a good range of accommodation for new postgraduate students and priority is given to international students. For further information about accommodation at Swansea see http://www.swan.ac.uk/accommodation/

In addition, information on accommodation at the bay campus can be found at http://www.swansea.ac.uk/engineering/bay-campus/accommodation/

Student Support Services

Email:student.services@swansea.ac.uk

Student Support Services is part of the Student Services Directorate alongside Residential Services (Accommodation Office) and the English Language Training Service (ELTS). It offers a 'one-stop-shop' to provide information, advice and support to students and staff working with them. It comprises:

- Disability Office
- International Student Advisory Service (ISAS)
- Money Advice - Student Financial Aid Office
- Student Counselling Service

For further information on what services the office provide see
http://www.swan.ac.uk/student-services/

Please note that each year the Student Services department at Swansea runs a meet and greet service to Heathrow on the weekend prior to the start of term. For more information see http://www.swansea.ac.uk/international/ prior to the start of the September term.

International Student Advisory Service (ISAS)

Email:ISAS@ Swansea.ac.uk

The International Student Advisory Service (ISAS) provides information, advice and support on non-academic matters to all international (non-UK) students and their dependants. The service operates according to the UKCISA / AISA Code of Ethics for those advising international students (http://www.ukcisa.org.uk/content/2705/UKCISA/AISA-Code-of-Ethics) and the Rules

and Code of Standards of the Office of the Immigration Services Commissioner (www.oisc.gov.uk/). Common areas of advice include UK immigration, travelling in the EU, financial hardship, employment regulations and advice regarding visiting friends and family. ISAS operates the Home Office Batch Scheme to assist students with extending their visas, and arranges Police Registration on campus. Specific induction sessions are arranged for international students.
The International Student Handbook is produced each year and sent to prospective students. It is also available on the University website at http://www.swan.ac.uk/isas/handbook/

Disabilities

Email:disability@swansea.ac.uk

The University Disability Office provides a wide range of support services for those with disabilities, including:

- Disability Office Manager – service management and development
- Caseworkers - a comprehensive advice and information service for students from initial enquiries prior to application and throughout their chosen course of study.
- Dyslexia Tutor – one to one tutorials and group presentations & workshops for students with Specific Learning Difficulties
- IT Support Officer – a help desk service to resolve problems with specialist technology and training on specialist software packages
- Mental Health Coordinator – advice and information for staff and students, individual student support and coordination with NHS Mental Health Services
- Support Coordinator – coordinates non-medical support recommended in students' assessment of needs reports e.g. notetakers, readers, mentors, subject specific support, sighted assistance etc.
- An Assessment and Training Centre, where students are able to receive an assessment of needs interview and report that considers the effects of students disability on study, makes recommendations for support (equipment, personal and consumable) and indicates the associated costs. The assessment report enables students to access the Disabled Students Allowance (DSA) from LEA's to fund the recommended support.
- The Recording for the Blind Centre, which works closely with colleagues in the Disability Office and Library and Information Centre to provide materials in Braille, large print and/or tape.

For further information about the range of services on offer, please visit the website at http://www.swansea.ac.uk/disability-office/ or consult the current Support Services Handbook for a summary.

Students Union

In addition the Student's Union operates an advice and support centre offering free confidential advice to all University students. For further information on what Swansea Students Union has to offer see http://www.swansea-union.co.uk/

Sports and Extra Mural Activities

For sports enthusiasts Swansea University's modern sports centre includes a fully equipped gym, multi-purpose sports hall, squash courts and a climbing wall. Next to this you will find the state-of-the-art 50m Wales National Pool. Outdoor facilities include rugby, football, lacrosse, cricket pitches and tennis courts. In addition, surfing and canoeing conditions on the Gower beaches are excellent.

For Arts enthusiasts the Taliesin Arts centre, based in the heart of campus, offers a lively programme of drama, dance concerts and an eclectic mix of films, including award winning foreign language titles not usually shown in mainstream cinema.

Study Support

A list of on-line resources for Study Skills support for students has been established at: http://www.swan.ac.uk/lis/

Language Classes

Free academic language support classes are also offered by the Centre for Applied Languages. Courses include general English, academic writing and reading and general study skills.

GENERAL REGULATIONS / ACADEMIC REGULATIONS

You should be aware that you must abide by the University's Academic Regulations and General Regulations, which are outlined on the Academic Services Website. http://www.swansea.ac.uk/academic-services/academic-guide/

SAFETY REGULATIONS & EMERGENCY PROCEDURES

The University's Safety Regulations are available for consultation on the main departmental notice board.

COMPLAINTS

Swansea University is committed to ensuring a high quality educational experience for its students, supported by appropriate academic, administrative and welfare support services and facilities. However there will be instances when students may feel dissatisfied with the teaching and learning, facilities or services provided by the University, or with the way the University, its students or its staff have acted or omitted to act. This may include unreasonable behaviour or an unsatisfactory level of service. It is expected that students and staff will make reasonable efforts to resolve matters at the outset and it is anticipated that the majority of complaints can be resolved satisfactorily on an informal basis.

In summary, the University operates a three-tier complaints system.

Stage 1: Informal Complaint
Stage 2: In writing to the relevant Head of Department/ School
Stage 3: Registering a formal complaint with Academic Services through filling in a formal University Complaint Form.

In addition, should a student on the programme be unable to resolve a complaint to their satisfaction within Swansea's procedures, he/she may approach the Board of Studies of the Consortium. An independent member of the Board will be asked to conduct an investigation into the complaint.

If you wish to make a complaint, please first read the section on the Academic Services Website http://www.swansea.ac.uk/academic-services/academic-guide/conduct-and-complaints/complaints-procedure/ outlining the University's full Complaints procedure.

VISAS FOR THE UNITED KINGDOM

If you come from a country outside the EU, you will need to apply for entry clearance in the form of a student visa or an entry clearance certificate at the British Embassy or High Commission in your country before you come to the UK.

Details of the visa application process can be obtained from the University web site at
http://www.swan.ac.uk/isas/immigration/applying-for-a-visa/
This guidance is frequently updated so please do check that you have the most up-to-date version before making an application.

1. What visa should I apply for?

- You normally apply for a Tier 4 (General) student visa. This visa is called **entry clearance**. You will first receive a visa vignette in your passport valid for 30 days from the date you say you wish to travel to the UK when you apply for the visa.
- The vignette visa gives you permission to enter the UK. You must then collect a biometric residence permit (BRP) from the university or from a designated Post Office within 10 days of entering. The BRP allows you to enrol and study at Swansea University and/or ICWS only and is valid for the duration of your course plus an extra 'wrap-up' period. See http://www.ukcisa.org.uk/Information--Advice/Visas-and-Immigration/Making-a-Tier-4-General-application-outside-the-UK for more details.
- If you are coming to study for six months or less (or for an English course of eleven months or less) and you will return to your country after the course, you can apply to enter the UK as a short-term student**.** See http://www.swansea.ac.uk/isas/immigration/what-visa/

2. How do I apply for a Tier 4 student visa?

- Do not apply for your visa more than three months before your course starts. For example, you must apply on or after 19th June 2016 for courses starting on 18th September 2016. Your CAS shows your course start date.
- Go to https://www.gov.uk/tier-4-general-visa/apply to apply online. Watch our Visa Video Guides to find out how to complete an online form http://www.swan.ac.uk/isas/immigration/visavideoguides/
- You may be required to take a credibility interview. See our web page for more information about this http://www.swan.ac.uk/isas/immigration/applying-for-a-visa.
- When you are completing the online application form, you must declare if you have had a visa refusal in the past and give details. You must also declare any warnings or cautions you have from the police or other authorities in any country, plus any fines (e.g. littering, council fines, parking tickets) even if they seem minor. Non-disclosure could result in your application being refused and a ban from entering the UK for up to 10 years. Email isas@swansea.ac.uk if you have more questions about this.

3. What documents do I need to apply for a Tier 4 student visa?

- Passport(s) (current and valid, and any old passports which are no longer valid with previous UK visas)
- UK Biometric Residence Permit (if you have previously been issued one)
- A recent passport-size photograph. Your photos must meet strict UK Visas and Immigration (UKVI) guidelines. See photo guidance: https://www.gov.uk/photos-for-passports
- The visa application fee £328 (as of March 2016)
- For each application there will also be an Immigration Health Surcharge payable in full at the time of application. The cost is £150 for each year of your visa. You can find further information on the Immigration Health Surcharge cost and how this is calculated at www.gov.uk/government/publications/immigration-health-surcharge-information-for-migrants
- Evidence of sufficient funding: for example a recent bank statement, bank letter or scholarship letter
- Confirmation of Acceptance for Studies (CAS) Statement (see Section 4 for details)
- Original of any document that is listed in the CAS statement, as evidence you used to be accepted by the University. For example, certificates from previous studies or the result of a language test.

- English language ability, if you are required to provide evidence of your English ability, you must provide evidence (Test certificate or reference number) of an IELTS UKVI test taken on or after 06 April 2015 or an appropriate Trinity language test. A list of approved English language tests and test centres is available at https://www.gov.uk/government/publications/guidance-on-applying-for-uk-visa-approved-english-language-tests
- A valid ATAS certificate (if needed – see Section 8 for more information)

4. Where can I get my CAS Statement?

The University will provide you with a statement to show that we have issued you with a Confirmation of Acceptance for Studies (CAS), stating that you will follow a full-time course.

Before the university can give you a CAS, university staff need to check whether you meet the requirements of the Tier 4 visa rules on academic progress and time limits on study. You need to answer questions and provide evidence of your previous study in the UK for the university to make these checks.

- **You may need to pay a fee deposit before you can receive the CAS.**
- If you are applying for a visa to start a course at Swansea University, get the CAS statement from the Admissions Office (email: admissions-enquiries@swansea.ac.uk)
- If you are applying for a visa to start an English language course, get the CAS statement from ELTS (email: elts@swansea.ac.uk)
- If you are applying for a visa to study with International College Wales Swansea (ICWS), get the CAS statement from ICWS (email: info@icws.swansea.ac.uk)

5. How much money do I need to show?

1st year course fee + £9135 (£1015 X 9 months). Funds must have been held for at least 28 days before application

You should keep more than the minimum in your account, in case of an unexpected payment. Any money you have paid towards your course fees can be deducted from the required total amount you have to show. To prove the amounts you have paid you will need to provide either an original paper receipt from the university or the amount paid must be shown on the CAS statement.

6. How do I show I have enough money?

The three main ways to show you have enough money are:

- **Bank statements** (in your own name or a joint account) covering a 28 day period. These must show that your money has not dropped below the required amount for the whole period and the statement must be less than one month old. You must maintain the required amount until you submit your visa application.
- **Parent/guardian's bank statements.** If you send these you must also include proof of your relationship, such as your original birth/adoption certificate, and an original signed and dated letter from them confirming their relationship to you and that the money is for your studies in the UK.
- **An official Scholarship letter.**
- See https://www.gov.uk/tier-4-general-visa/documents-you-must-provide for full details of the information which must be in these documents.

7. What if some of my documents are not in English?

If any of your documents are **not in English**, the original must be sent with a fully certified translation by a professional translator. This translation must include the following information: The translator's qualifications, confirmation from the translator that it is an accurate translation of the original document, the translator's contact details, date of translation, translator's original signature plus the full name of the translator or of an authorised official of the company.

8. Do I need an ATAS certificate?

If you are a postgraduate student studying a designated subject, you need a valid ATAS clearance certificate. See https://www.gov.uk/academic-technology-approval-scheme to see if you need an ATAS clearance certificate.

9. Can my family come with me to the UK as my dependants?

If you wish your family members to come with you to the UK, please read http://www.ukcisa.org.uk/International-Students/Immigration-/Dependants/ carefully, as your family will not be able to come with you in all cases. Visit our website http://www.swan.ac.uk/isas/immigration/tier4dependants/ for more information.

10. What if I need more help with my visa application?

If you require further assistance after reading this information, contact the International Student Advisory Service at Swansea at isas@swan.ac.uk

Once you successfully obtain your visa, please check that it is valid for the full period of your time in Swansea before you travel to the UK. If the visa does not cover the whole period of course, contact the VAC to request a correction.

For full information on applying for entry clearance to the UK, please visit the UK Border Agency's Visa Services website (http://www.ukba.homeoffice.gov.uk/). Alternatively, you can contact the British Embassy in your home country.

INFORMATION ON Ecole Centrale Nantes

THE CITY

Nantes is a city in western France, located on the Loire River, 50 km (31 mi) from the Atlantic coast. The city is the 6th largest in France, while its metropolitan area ranks 8th with over 800,000 inhabitants. Nantes is the capital city of the Pays de la Loire region and Loire-Atlantique département. Together with Vannes, Rennes and Carhaix, it was one of the major cities of the historic province of Brittany, and the ancient Duchy of Brittany. In 2004, Time described Nantes as "the most liveable city in Europe". In 2010, Nantes was named a hub city for innovation in the Innovation Cities Index by innovation agency, 2thinknow. The city was ranked 36th globally from 289 cities and 4th overall in France, across multiple sectors of the economy.

More info on the city :

http://en.nantes-tourisme.com/

THE SCHOOL

Founded in 1919, the Ecole Centrale de Nantes (ECN) is among the best higher education and research institutions in France in the fields of Science and Engineering. Centrale Nantes is a public institution belonging with the Ministry of Research and Education and receives government support. The purpose of the Ecole Centrale of Nantes is to develop top level future scientists and engineers in multidisciplinary as well as specific fields. For around 2 000 students per year in engineering programme, Master's Degrees and PhDs. ECN Professors, Administrative and Alumni play an important role in improving national and international education research and corporate sectors. Centrale Nantes engineers learn and master the complexity of industrial projects and are sensitive to the needs of the society in order to conceive products and services for the benefit of the society as a whole. Widespread recognition of the ECN programs by firms and R&D organizations has enabled graduates to assume positions of responsibility in every sector—among them aeronautics and space, automobiles, construction and public works, electronics, information sciences, mechanics, nuclear energy, offshore operations, the oil business, scientific and technical research, consulting, and banking.

Centrale Nantes has developed a strong international policy covering both training and research: Hotbeds of innovation and open-mindedness, the research laboratories of Centrale Nantes provide strong links with the French industrial fabric and enjoy a reputation for excellence in Europe and around the world (Ranked as Excellent A and A+ by national public agency of evaluation). The ECN research units possess experimental equipment that is unique in their respective fields, particularly in naval hydrodynamics, fluid mechanics, civil engineering, crash testing, composite and advanced materials, virtual reality, concurrent engineering, and machining. ECN research teams are highly involved of the European 7th PCRD project (10 projects in 2011, 1 as leader). More than 100 contracts are processed annually, in accordance with public bodies, large groups and small- to medium-sized businesses. These contracts represent 31% of Centrale Nantes annual running costs budget. ECN is also member of three international laboratories in China and Japan.

At the heart of its strategic policy since 1991, the international development of Ecole Centrale de Nantes has gained significant national and international recognition, visibility attractiveness and experience. Ecole Centrale de Nantes privileges its participation in the development of the European area as a major asset of its international policy, by meeting the expectations of the Bologna Process and by piloting and participating in European projects such as Erasmus, Erasmus Mundus, Tempus. ECN is an Erasmus mobility programme active member. ECN is currently involved in 3 Erasmus Mundus Master programmes as well as in 3 Erasmus Mundus External Cooperation Window programmes. ECN is an active member of international networks such as T.I.M.E. Top Industrial Managers for Europe is a leading network for the training of multi-cultural engineers: Master-level Double Degree graduates. It is also an active member of RMEI Network (Mediterranean Network of Engineering Institutions) and more recently Maghales (Latin America). Along with its French partners (Groupe des Ecoles Centrales), ECN developed a strong expertise in the creation and the implementation of Double Degree agreements. ECN was at the origin of the creation of the first Double Degree Agreement between French HEI and non-Europeans HEIs at the Engineering Master Level (China 1996, Brazil 2000, Japan 2005 and more recently in 2011 with Anna Universality in India). ECN intends to reinforce its involvement for the implementation of Joint Degree agreements.

Understanding the importance of international experience, ECN has made a minimum stay abroad mandatory for all its home students. Within their engineering curriculum, 100% ECN students, at the engineering programme, leave the ECN for either a Double-Degree (2 years abroad) or 1 or 2 exchange semesters. Since 2007, the rate of incoming students has increased every year by 20%. In 2012, 24% of the ECN students are international. The rich ECN experience in hosting/sending students and staff has recently widely developed with its participation in various EM Action 1 and 2 programmes. ECN has set up new application and evaluation tools. ECN has now a deep knowledge of the grading/evaluation systems of the whole world, which enables the School to assess and rank the students correctly.

The International Office (IO) counts 17 members. 5 full-time members work on the development, the implementation and the quality control of international activities. About 12 additional staff members (administrative, academic or research) are dedicated to geographical zones. Every year, the IO staff is involved in the ECN exchange programmes launching and publicity and in their selection process. Applications of incoming and outgoing students are managed by the IO team using electronic applications and interviews at home university. Once the incoming students have been selected for Ecole Centrale de Nantes, each one gets an academic as well as a cultural tutor, who will help him/her to construct his/her learning plan. The administration staff has a long-lasting experience in supporting students in all aspects including housing (student rooms are automatically booked for exchange students by our International Office), visa requirements, residence permits, bank account openings, local area visits, etc. The administration supports the students in all their procedures, i.e. before their arrival, on their arrival, during their stay in Nantes, and after their return to their home university. French courses are offered all year round according to the level of the students. Centrale Nantes also offers courses in 7 various languages, including French as a foreign language. Centrale Nantes also organises get–together weekends among students, with local area and town visits.

ECN is a member of the Ecoles Centrales Group (Groupe des Ecoles Centrales with Lille, Lyon, Marseille and Paris) with more than 6,500 students in Engineering Sciences. ECN is a founding member of the regional Pôle de Recherche et d’Enseignement Supérieur (PRES UNAM) with more than 76,000 students and 2300 PhD.

More on the school :

http://www.ec-nantes.fr/version-anglaise/

International Student Contact and Reception :

international@ec-nantes.fr

Part I

Swansea University & Universitat Politècnica de Catalunya/CIMNE

MSc modules distribution

1st Semester Swansea University

(30 ECTS)

Compulsory Modules	**ECTS**
Numerical Methods for Partial Differential Equations	5
Finite Element Method	5
Continuum Mechanics	5
Advanced Fluid Mechanics	5
Transversal modules (compulsory)	
Communication skills in a foreign language	5

1st Semester UPC/CIMNE

(30 ECTS)

Compulsory Modules	**ECTS**
Numerical Methods for Partial Differential Equations	5
Finite Element Method	5
Continuum Mechanics	5
Advanced Fluid Mechanics	5
Transversal modules (compulsory)	
Communication skills in a foreign language	5

2nd Semester Swansea University

(30 ECTS)

Structural Engineering Elective Modules	**ECTS**
Computational Plasticity	5
Nonlinear Continuum Mechanics	5
Fluid Structure Interaction	5
Fluid Mechanics Elective Modules	**ECTS**
Computational Fluid Dynamics	5
Reservoir Modelling and Simulation	5
Transversal modules (compulsory)	
Entrepreneurship for engineers	5
Industrial placement (compulsory)	**ECTS**
Practical training	15

2nd Semester UPC/CIMNE

(30 ECTS)

Structural Engineering Elective Modules	**ECTS**
Computational Solid Mechanics	5
Computational Structural Mechanics and Dynamics	5
Finite Elements in Fluids	5
Industrial placement (compulsory)	**ECTS**
Practical training	15

1st Semester modules – UWS/UPC

NUMERICAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS		
Credits: 5 **Semester:** 1 **Compulsory**: YES		
Format:	Lectures Examples Private study	25h 15h 98h
Lecturer (UWS): M. G. Edwards **Lecturer (UPC) : Antonio Rodriguez-Ferran**		

Contents:

This module presents the fundamentals of modern and classical numerical techniques for linear and nonlinear partial differential equations, with application to a wide variety of problems in science, engineering, and other fields. Topics include Finite Difference, Finite Volume and Boundary Element discretizations, and an overview of direct and iterative methods for systems of equations as well as a basic review of numerical methods for eigenvalue problems.

1. Overview of partial differential equations
2. Finite difference methods for elliptic equations
3. Finite difference methods for parabolic equations (including consistency, stability and convergence issues)
4. Finite difference methods for hyperbolic equations
5. Introduction to finite volumes
6. Introduction to integral equation methods and boundary elements
7. Solution techniques:
   a. Direct solution methods and their implementation
   b. Iterative solvers (stationary and Krylov methods)
   c. Overview of techniques for Eigenvalue problems

Intended Learning Outcomes: to demonstrate

A knowledge and understanding of:	The fundamentals of the behaviour and numerical approximation of partial differential equations; truncation error and solution error; consistency, stability and convergence; direct and iterative solution of linear systems of equations and eigenvalue problems.
an ability to: (thinking skills)	Understand and formulate basic numerical procedures and solve illustrative problems; identify the proper methods for the corresponding PDE.
an ability to: (practical skills)	Understand practical implications of behaviour of numerical methods and solutions; logically formulate numerical methods for solution by computer with a programming language (Matlab, Fortran 77 or C).
an ability to: (key skills)	Study independently; use library resources; use a personal computer for basic programming; effectively take notes and manage working time.

Assessment: 30% continuous assessment assignments, 70% from end of Semester examination (50% open-book).

Practical Work: Exercises will be set, which will involve coding some of the presented methods.

Recommended texts: Lecture notes
Hoffman, J.D., *Numerical Methods for Engineers and Scientists*, McGraw-Hill, 1992
Smith, G.D., *Numerical Solution of Partial Differential Equations*, Oxford University Press,1986
Further Readings: Leveque, R., *Numerical Methods for Conservation Laws*, Lectures in Mathematics, ETH Zürich, 1992

CONTINUUM MECHANICS

Credits: 5 **Semester:** 1 **Compulsory**: YES

Format:	Lectures Examples Private study	25h 15h 98h

Lecturers (UWS): D. Peric and D.R.J. Owen
Lecturer (UPC) : C. Angelet de Saracibar

Contents:

A fully comprehensive module on nonlinear continuum mechanics for engineers with an in-depth review of fundamental concepts, including motion, descriptions, strains, stresses, balance laws, variational principles and an introduction to computational plasticity.

1. Tensor algebra and analysis (definitions, invariants, gradient, divergence, curl, integral theorems,…)
2. Kinematics: movement and deformation (deformation tensors)
3. Small strains and compatibility
4. Stress tensors
5. Balance principles
6. Constitutive theory (laws of thermodynamics, strain energy, elasticity)
7. Boundary value problems of linear elasticity (2D)
8. Introduction to plasticity (von Mises, Tresca, Mohr Coulomb)
9. Ideal fluids and potential flow
10. Viscous incompressible flow (with an introduction to turbulence)

Intended Learning Outcomes: to demonstrate

a knowledge and understanding of:	fundamentals of solid mechanics with application to elasticity; fundamentals of fluids mechanics.
an ability to: (thinking skills)	understand different aspects (geometry, equilibrium and constitutive theory) of formulating engineering problems in solid and fluid mechanics, realize the difficulties in obtaining closed form solutions and a necessity for approximation techniques.
an ability to: (practical skills)	develop practical skills related to tensor calculus; formulate and perform analysis of several classes of engineering problems in solid and fluid mechanics.
an ability to: (key skills)	study independently; use library resources; effectively take notes and manage working time.

Assessment: 70% from end of Semester examination (40% use of lecture notes allowed), 30% by course work.

Recommended Texts: Lecture notes
Holzapel, G.A., *Nonlinear Solid Mechanics, a Continuum Approach for Engineering*, Wiley, 2000
Currie, I.G., *Fundamentals Mechanics of Fluids*, 2nd Edition, McGraw Hill, 1993.

FINITE ELEMENT METHOD

Credits: 5 **Semester:** 1 **Compulsory**: YES

Format:	Lectures Examples Private study	25h 15h 98h

Lecturer (UWS): R. Sevilla
Lecturers (UPC): E. Oñate and P. Díez

Contents:

This module introduces the basic concepts of the Finite Element Method (FEM), including derivation of formulations, analysis of the resulting methods and essential aspects of the implementation. The presentation is motivated by linear practical problems (heat transfer, elasticity, etc.) and it is illustrated and complemented with hands-on applications.

1. Weighted residuals
2. Boundary conditions
3. Finite element discretization
4. 1D Applications (Bar under axial loading, heat flow)
5. 2D Applications (Heat flow, Torsion of elastic bars, Seepage flow, Irrotational flow)
6. Linear elasticity (Plane strain, plane stress)
7. Isoparametric transformation
8. Numerical integration,
9. Introduction to finite element implementation

Intended Learning Outcomes: to demonstrate

a knowledge and understanding of:	the fundamentals of linear finite elements; the derivation of weak forms and their resolution; why finite elements approximate the solution of a PDE; the basic structure of a FE code; how to solve transient problems.
an ability to: (thinking skills)	identify the key issues when performing a finite element analysis of an engineering problem; employ appropriate order polynomials together with appropriate integration rules; identify different methods for prescribing boundary conditions.
an ability to: (practical skills)	solve linear solid mechanics and heat transfer problems by hand using FE; use a simple FE computer code to set up and produce results for computational simulation of simple engineering problems; formulate and implement simple key aspects of a FE code.
an ability to: (key skills)	study independently; use library resources; use a personal computer for solving FE problems and do some basic programming; effectively take notes and manage working time.

Assessment: 40 % continuous assessment assignments, 60% from end of Semester open-book examination

Practical Work: Exercises will be set which will involve use of a FE program and some coding.

Recommended texts: Lecture notes
Zienkiewicz, O.C.; Morgan, K., *Finite Elements and Approximation*, Wiley, 1983
Hughes, T.J.R., *The Finite Element Method*, Prentice-Hall,1987
Further Readings: Henwood, D.J., Bonet, J., *Finite Elements – A Gentle Introduction*, Macmillan, 1997
Zienkiewicz, O.C.; Taylor, R.L., *The Finite Element Method: 1 Basic Formulation and Linear Problems*, Elsevier, 2005

ADVANCED FLUID MECHANICS

Credits: 5 **Semester:** 1 **Compulsory**: NO

Format:	Lectures	20h
	Examples	10h
	Private Study	95h

Lecturer (UWS): K. Morgan
Lecturer (UPC): Yongxing Shen

Contents:

1. Introduction. Vectors and tensors. Basic concepts. Classical theorems (6hrs)
2. Governing Equations (6hrs)
3. Dimensional analysis and modeling (3hrs)
4. Hydrostatics (2hrs)
5. Ideal fluid flow (4hrs)
6. Viscous flow (3 hrs)
7. Boundary layer theory (6hrs)

Intended Learning Outcomes: to demonstrate

a knowledge and understanding of:	Fundamentals of theoretical fluid mechanics including how scaled experiments may be constructed and the results interpreted
an ability to: (thinking skills)	Formulate problems involving different classes of flow
an ability to: (practical skills)	Use classical and simple numerical techniques to solve problems in fluid mechanics
an ability to: (key skills)	Study topics in depth independently and use library resources. Effectively take notes and manage working time.

Assessment: 50% continuous assessment assignments, 50% from end of Semester closed book examination

Recommended texts: James A. Fay, *Introduction to Fluid Mechanics*, MIT Press, 1994.

I.G. Currie, *Fundamental Mechanics of Fluids*, 2nd edition, McGraw Hill International Editions, 1993.

Further Reading: A.R. Patterson, *A First Course in Fluid Dynamics*, Cambridge University Press, 1983.

A.J.Chorin & J.E. Marsden, *A Mathematical Introduction to Fluid Mechanics*, Springer-Verlag, 1979.

ENTREPENEURSHIP FOR ENGINEERS

Credits: 5 **Semester:** 1 **Compulsory**: YES

Format:	Lectures Examples classes Private study	22h 4h 74h

Lecturers (UWS): K. Board
Lecturers (UPC): P. Losantos

Contents:

1. What is an entrepreneur and why enterprise matters: the six dimensions of entrepreneurship, structure and presentation of opportunities, sources and structure of finance, people and teams
2. How enterprise is managed internationally, managing early and long-term growth, harvesting and buy-out, sustaining the flow of ideas within a company, case-studies.

Intended Learning Outcomes: to demonstrate

a knowledge and understanding of:	- Describe how opportunities are identified and a business plan is generated in order to get started - List the sources of finance that exist and how they are structured - Analyse the role of people and what makes a winning team
an ability to: (thinking skills)	- Discuss a case history that lead to success
an ability to: (practical skills)	- Explain how early growth is managed
an ability to: (key skills)	- Analyse how failure can occur and how to guard against it - Explain how enterprise can be sustained within an organisation as it grows

Assessment: Combination of interactive lectures and self-study

Recommended texts: Mastering Enterprise, Financial Times Publication.
Simon Bridge et al, (R) Understanding Enterprise, Entrepreneurship and Small Business, Palgrave Macmillan.

COMMUNICATION SKILLS IN A FOREIGN LANGUAGE

Credits: 5	**Semester:** 1	**Compulsory**: YES
Format:	Lectures Examples Private study	15h 15h 95h

Lecturers: To be allocated

Module aims:

In this module, students will be exposed to basic communication skills in a chosen foreign language (e.g. French, German, Spanish). This module is designed for students with little or no previous knowledge of the chosen foreign language.

The aim of the module is to enable students to acquire a basic vocabulary and an understanding of fundamental grammatical structures so as to allow them to communicate in a written and spoken manner. Students will also acquire awareness of contemporary foreign culture from the range of materials used.

Intended Learning Outcomes: to demonstrate

a knowledge and understanding of:	Methods of delivery of oral presentations. Logical structure of scientific texts (including standards of referencing).
an ability to: (thinking skills)	- To enable students to acquire a basic vocabulary of the foreign language. - To enable students to acquire a basic understanding of fundamental grammatical structures of the foreign language.
an ability to: (practical skills)	- To enable students to communicate in a basic written and spoken manner in a foreign language. - To provide students with basic awareness of contemporary foreign culture from the range of materials used.
an ability to: (key skills)	- To help students develop basic technical communication skills from the range of materials used, such as technical papers, chapters of books or recorded lectures/presentations in the chosen foreign language.

Assessment: The method of assessment as established by the College of Arts and Humanities.

Recommended texts:

Voila: a course in French for adult beginners; Hodder Education, J. Gonthier and C. Geoghegan; ISBN: 978-0340813676.

¡En Marcha!; Hodder Arnold; Carmen García del Río; ISBN: 978-0340809051

Passwort Deutsch: Kurs Und Ubungsbuch; Verlag; Klett, Ernst; ISBN: 978-3126758079

2nd Semester modules – Swansea University

COMPUTATIONAL PLASTICITY		
Credits: 5	**Semester:** 2	**Compulsory**: NO

Format:	Lectures	21h
	Examples	15h
	Private study	89h

Lecturers: D. Peric

Contents:

1. Introduction: Historical Perspective. Physical Motivation. Rate Independent Plasticity. Rate Dependence. Creep. Rheological Models. [1]
2. 1-D Mathematical Model: Yield Criterion. Flow Rule. Loading / Unloading Conditions. Isotropic and Kinematic Hardening Models. 1-D Elasto-Plastic Boundary Value Problem. [2]
3. Computational Aspects of 1-D Elasto-Plasticity: Integration Algorithms for 1-D Elasto-Plasticity. Operator Split. Return Mapping. Incremental Elasto-Plastic BVP. Consistent Tangent Modulus. [3]
4. Classical Model of Elasto-Plasticity: Physical Motivation. Classical Mathematical Model of Rate-Independent. Elasto-Plasticity: Yield Criterion. Flow Rule. Loading / Unloading Conditions. [2]
5. Computational Aspects of Elasto-Plasticity: Integration Algorithms for Elasto-Plasticity. Operator Split. The Trial Elastic State. Return Mapping. Incremental Elasto-Plastic BVP. Consistent Tangent Modulus. [3]
6. Plane Strain Von Mises Elasto-Plastic Model: Continuum. Integration Algorithm. Operator Split. The Trial Elastic State. Return Mapping; Incremental Elasto-Plastic BVP: Consistent Tangent Modulus. [3]
7. Integration Algorithms for Generalised Elasto-Plasticity: Stress Integration Algorithm. Example: Stress Integration Algorithm for the Barlat Anisotropic Yield Criterion. [2]
8. Computational Aspects of 1-D Large Strain Elasto-Plasticity: 1-D Mathematical Model: Multiplicative Elasto-Plastic Split. Logarithmic Stretches. Hencky's Strain Energy. Yield Criterion. Flow Rule. Isotropic Hardening Model. 1-D Elasto-Plastic BVP. Integration Algorithms for 1-D Large Strain Elasto-Plasticity. Backward Euler. Operator Split. Return Mapping. Exponential Map. Incremental Elasto-Plastic BVP. [3]
9. Generalisations and Applications of Plasticity: Plasticity Theory of Friction. Plasticity in Engineering Practice: Metal Forming. Impact Dynamics and Crashworthiness. Geomechanics. [2]

Intended Learning Outcomes: to demonstrate

a knowledge and understanding of:	Fundamentals of computational modelling of inelastic materials with emphasis on rate independent plasticity. A sound basis for approximation methods and finite element method, in particular.
an ability to: (thinking skills)	Understand different methodologies for discretisation of different time evolution problems, and rate-independent elasto-plasticity in particular.
an ability to: (practical skills)	Develop practical skills related to modelling of inelastic history dependent materials. Formulate and implement a computational procedure for integration of rate-independent elasto-plasticity in 1-D. Perform analysis of engineering problems in elasto-plasticity by employing a commercial finite element package.
an ability to: (key skills)	Study independently and use library resources. Develop programming skills and ability to use commercial software. Effectively take notes and manage working time.

Assessment: 50% by examination (closed book exam), 50% by course work.

Practical work: Attendance is a requirement. The coursework will consist of three small projects that will require both hand calculation and computer simulations. Computer simulation will require certain amount of programming and use of the existing finite element software package Elfen. The project reports should consist of two parts: (i) a discussion related to general aspects of formulation and computational treatment of the problem under consideration, (ii) description of numerical solution of an individual problem.

Recommended texts: Lecture Notes

Further Readings: M.A. Crisfield: Basic plasticity Chapter 5. in: Non-linear Finite Element Analysis of Solids and Structures. Volume1: Essentials , John Wiley, Chichester, 1991

J.Lemaitre and J.-L. Chaboche: Mechanics of Solid Materials , Cambridge University Press, Cambridge, 1990

J. Lubliner: Plasticity Theory , Macmillan, New York, 1990

D.R.J.Owen and E.Hinton: Finite Elements in Plasticity: Theory and Practice Pineridge Press, Swansea, 1980

J. C. Simo and T. J. R. Hughes, Computational Inelasticity, Springer, 1998.

O.C.Zienkiewicz and R.L.Taylor: Inelastic and non-linear materials, Chapter 3 in The Finite Element Method. Volume 2: Solid Mechanics, 5-th edition, Butterworth-Heinemann, Oxford, 2000.

NONLINEAR CONTINUUM MECHANICS

Credits: 5 **Semester:** 2 **Compulsory**: NO

Format:	Lectures	20h
	Examples	10h
	Private study	95h

Lecturers: A.J. Gil

Contents:

1. **Introduction:** Categories of nonlinear continuum and structural analysis, Simple beam and column examples, Alternative strain measures, Simple truss example, Introduction to solution process, Mathematical preliminaries; vectors, tensors, directional derivative, linearization, Newton-Raphson solution.
2. **Kinematics:** Material and spatial descriptions of motion, Deformation gradient and strain tensors, Polar decomposition, Volume and area relations, Velocity gradient and rate of deformation tensors.
3. **Stress and Equilibrium:** Cauchy stress tensor, Spatial equilibrium and virtual velocity equations, Work conjugacy and alternative expressions of equilibrium, Alternative stress tensors.
4. **Constitutive Equations:** Hyperelasticity, elasticity tensor, isotropic elasticity
5. **Linearized Equilibrium Equations:** Newton-Raphson re-visited, Linearized spatial equilibrium equations, [Equilibrium & Total Potential Energy]
6. **FE Discretization and Solution:** Kinematics, Equilibrium, Linearized equilibrium, Newton-Raphson solution.

Intended Learning Outcomes: to demonstrate

a knowledge and understanding of:	The fundamentals of finite deformation analysis, why such an analysis is nonlinear and how finite deformation problems can be established and solved numerically using the finite element method.
an ability to: (thinking skills)	Formulate and solve simple geometrically nonlinear problems using the Newton-Raphson method. Undertake exercises illustrating various aspects of geometrically nonlinear kinematics.
an ability to: (practical skills)	Develop practical skills related to modelling of geometrically nonlinear problems. Perform analysis of geometrically nonlinear problems by employing a finite element package.
an ability to: (key skills)	Study independently and use library resources. Effectively take notes and manage working time.

Assessment: 30% project work, 70% open book exam

Recommended Texts:

Bonet, J. and Wood. R. D. *Nonlinear Continuum Mechanics for Finite Element Analysis*, Cambridge Univ. Press, 1997, ISBN 0-521-57272-X.

Belytschko, T., Wing. L. K. and Moran, B. *Nonlinear Finite Elements for Continua and Structures*, Wiley, 2001, ISBN 0-471-98774-3 (paperback)

Holzapfel, G. A., *Nonlinear Solid Mechanics- a Continuum Approach for Engineering*, Wiley, 2000, ISBN 0-471-82319-8 (paperback).

Crisfield, M., *Nonlinear Finite Element Analysis of Solids and Structures*, Vos. 1 & 2, 1991, 1997, Wiley, ISBN 0-471-92956-5, ISBN 0-471-95649-X.

Malvern, L.E., *Introduction to the Mechanics of Continuous Media*, Prentice Hall, 1969.

Spencer, A. J. M., *Continuum Mechanics*, Longman, 1980, (out of print).

FLUID-STRUCTURE INTERACTION	
Credits: 5 **Semester:** 2 **Compulsory**: NO	
Format: Lectures Example classes/Tutorials Directed private study	
Lecturer: WG. Dettmer	
Assessment: course work (40%), written examination (60%)	
Module content: [lecture hours] • **Fluid-Structure Interaction and Classical Aeroelasticity** [12] aerodynamic forces, lift curves, drag polars, static problems, vortex induced vibration, lock-in, galloping, flutter, various applications • **Solution Strategies for Coupled Problems** [8] model problem, monolithic and partitioned schemes, weak and strong coupling, staggered schemes, iterative strategies, relaxation, inexact and exact block Newton-Raphson methods • **Numerical Modelling of Fluid-Structure Interaction** [10] review of basics of numerical modelling of fluid flow and structural dynamics, interface tracking/capturing, fluid flow on moving domains, interface modelling, introduction to in-house computer programme, example problems	
Practical work: some analytical solutions, analysis of the model problem, solution of selected problems with the in-house computer programme.	
Intended Learning Outcomes: After completing this module you should be able to demonstrate:	
a knowledge and understanding of:	different phenomena of fluid-structure interaction, different solution strategies for coupled problems, difficulties associated with the numerical modelling of fluid-structure interaction
an ability to: (thinking skills)	predict qualitatively the behaviour and the likeliness of instabilities of an aeroelastic system, formulate solution procedures for systems of coupled nonlinear equations
an ability to: (practical skills)	calculate estimates of the frequency and amplitude of flow-induced structural oscillations, calculate estimates of the critical fluid velocity in aeroelastic stability problems, write computer programmes for the solution of systems of coupled nonlinear equations, simulate fluid-structure interaction problems with the in-house code
an ability to: (key skills)	study independently, use library resources, effectively take notes and manage working time
Recommended texts: R. D. Blevins, *Flow Induced Vibration*, Van Nostrand Reinhold Company, New York, 1977 or other editions, selected scientific papers, lecture notes	
Further Reading:	
Additional notes: **none**	

COMPUTATIONAL FLUID DYNAMICS

Credits: 5 **Semester:** 2 **Compulsory**: NO

Format:	Lectures	20h
	Examples	20h
	Private study	85h

Lecturers: P. Nithiarasu

Contents:

1. Introduction to CFD [1]
2. CFD model and applications [1]
3. Navier-Stokes equations [2]
4. Mathematical nature of equations [3]
5. Examples [2]
6. Spatial and temporal discretizations and examples [4]
7. Mini-project briefs [1]
8. Finite difference and finite volume schemes and examples [4]
9. Stabilized solution algorithms and examples [4]
10. Advanced topics [2]
11. Review and assessment [2]

Computer laboratory work: associated with mini-projects.
Project work: Mini-projects on computer implementation.

Intended Learning Outcomes: to demonstrate

a knowledge and understanding of:	Fluid dynamics equations, spatial and temporal discretizations and relevant mathematical aspects
an ability to: (thinking skills)	Identify the key issues relevant to discretization both in space and time. Set up appropriate initial and boundary conditions.
an ability to: (practical skills)	Implement and use computer programmes to solve fluid dynamics problems. Use any one programming language to develop computer codes. Use mesh generators to produce appropriate meshes for analysis. Identify appropriate boundary nodes to implement the boundary conditions. Use post processing soft-wares and produce graphical representation of results
an ability to: (key skills)	Submit projects in time. Produce project reports.

Assessment: Written closed-book examination (70%), projects (30%).

Penalty for late submission of continual assessment assignment:

No marks awarded for late submissions.

Project work: Two projects. One on schemes and another on application.

Recommended Texts:

Text: Module notes

C. Hirsch, *Numerical Computation of Internal and External Flows*, Vol 1 and Vol 2, Wiley, 1989.

O.C. Zienkiewicz, R. L. Taylor and P. Nithiarasu, *The Finite Element Method for Fluid Dynamics*, 6th Edition, Elsevier, 2005.

R.W. Lewis, P. Nithiarasu and K.N. Seetharamu, *Fundamentals of the Finite Element Method for Heat and Fluid Flow*, Wiley, May 2004.

RESERVOIR MODELLING AND SIMULATION		
Credits: **5** Semester: **2** Compulsory**: NO**		
Pre-requisite modules:	Engineering Mathematics: Level III	
Format:	Lectures Examples Directed Private Study	20h 10h 70h
Lecturer: M.G. Edwards		
Module content:		
Introduction to petroleum reservoirs; the flow variables, medium variables. Equation Types; Principles of mass conservation Single phase flow, Darcy's Law Potential Flow Permeability tensors and Upscaling. Layered medium and flow. Well model and radial flow. Multiphase flow, Darcy's Law Buckley Leverett Flow. Oil recovery calculation Unstable flow Flow on an incline		
Intended Learning Outcomes: to demonstrate		
a knowledge and understanding of:	The basic principles of mass conservation and formulation of conservation laws according to equation type. Their fundamental solutions. Upscaling while maintaining medium properties. Stable and unstable flow regimes. Effect of mobility ratio on oil recovery and water breakthrough.	
an ability to: (thinking skills)	Understand and formulate flow models, boundary conditions and procedures to solve illustrative problems. Appreciate the coupled form of the general system of equations.	
an ability to: (practical skills)	Understand and interpret practical implications, limitations of flow model solutions and use of models in simulation.	
an ability to: (key skills)	Study independently, use library resources. Effectively take notes and manage working time.	
Assessment: 25% continuous assessment assignments, 75% closed book examination. Practical Work: Exercises/project given during course		
Recommended texts: Lecture notes Dake L., *Fundamentals of Reservoir Engineering*, Elsevier 1978 Bear J, *Dynamics of Fluids in Porous Media*, Dover Edition 1988 Crichlow, *Modern Reservoir Engineering – A Simulation Approach*, Prentice Hall 1977		

2nd Semester modules – UPC/CIMNE

COMPUTATIONAL SOLID MECHANICS

Credits: 4 **Term:** 2 **Compulsory**: YES

Format:	Lectures Examples Private study	20h 12h 78h

Lecturers: J. Oliver

Contents:

This module focuses on numerical methods applied to modeling non-linear material behaviour in solids. Emphasis is done in the integration of the constitutive models and the insertion of material non-linearity in finite element settings. The presentation covers both the essential theoretical aspects as well as hands-on applications.

1. Constitutive modeling of materials
2. Elasticity and visco-elasticity
3. Continuum damage and visco-damage
4. Plasticity and visco-plasticity
5. Material stability
6. Computational techniques in non-linear material modeling of solids.
7. Advanced topics: contact mechanics and extension to finite strains.

Intended Learning outcomes: to demonstrate

A knowledge and understanding of:	the fundamentals of the behaviour of engineering materials and their numerical modeling.
an ability to: (thinking skills)	understand and identify the key issues relevant to material modeling: identification of the dissipation mechanisms associated to each non-linear behaviour; set up the physically meaningful values for the material properties; identify the proper numerical methods for solving the solids mechanics problem.
an ability to: (practical skills)	implement and use computer programs to solve solid mechanics problems accounting for material non-linearity; use any one programming language to develop computer codes; use mesh generators to produce appropriate meshes for analysis; use post-processing software and produce graphical representation of results.
an ability to: (key skills)	study independently; use library resources; submit the projects in time; produce project reports and present them.

Assessment: 50% continuous assessment assignments, 50% from end of Term examination (50% open-book).

Practical Work: Exercises will be set, which will involve coding some of the presented methods.

Recommended texts:

Belytschko T., Liu W.K., Moran B., *Non-linear Finite Elements for Continua and Structures*, Wiley, 2002

Simo J.C, Hughes T.J.R., Computational Inelasticity, Springer, 1997

COMPUTATIONAL STRUCTURAL MECHANICS AND DYNAMICS

Credits: 4 **Term:** 2 **Compulsory**: YES

Format:	Lectures Examples Private study	20h 12h 78h

Lecturers:, E. Oñate, A. Barbat, F. Zárate

Contents:

This module presents the concepts, formulations and applications of the finite element method for analysis of structures with classical and new materials (composites) under static and dynamic loading. The focus is on linear problems, although a brief introduction to non linear structural analysis is also given. The different methods cover the most common structural typologies found in engineering practice, such as dams, tunnels, tanks, shells, buildings, bridges, mechanical components, sheet metal parts, etc.
Details of the FEM formulation are given in each case together with a description of the key computational aspects, aiming to introduce students to the programming of the FEM for structural analysis.
The module lectures are complemented with hands-on applications of the FEM to the analysis of a wide range of structures.

1. Basic concepts of matrix analysis of bar structures.
2. 2D solids.
3. Axisymmetric solid
4. Three dimensional solids.
5. Beams.
6. Thick and thin plates.
7. Folded plate and curved shells
8. Axisymmetric shells
9. Structural dynamics analysis.
10. Introduction to non linear structural analysis
11. Miscellaneous topics

Intended Learning outcomes: to demonstrate

A knowledge and understanding of:	The fundamental of the theory and practice of finite element method for analysis of structures under static and dynamic loading; the basic theoretical aspects for the analysis of each structure; the computational aspects involved in the structural analysis.
an ability to: (thinking skills)	identify the appropriate finite element theory for the analysis of a particular structure; select the correct FEM solution strategy; have a critical appraisal of the numerical results
an ability to: (practical skills)	be able to analyze most structural types found in practice using the FEM; be able to use commercial FEM codes for structural analysis; be able to develop a basic FEM code for structural analysis
an ability to: (key skills)	study structural analysis independently; use library resources; solve structural analysis problems in personal computers; do some basic programming of FEM for structural analysis; be able to pursue advanced modules in structural analysis; effectively managing working time

Assessment: 70% from end of Term examination (50% open book), 30% by course work

Recommended texts: Lecture notes
Further readings: O.C. Zienkiewicz and R.L. Taylor. *The finite element method*. Vols. 1 and 2, 5th Edition, Butterworth-Heinemann, 2003.

FINITE ELEMENTS IN FLUIDS

Credits: 4 **Term:** 2 **Compulsory**: YES

Format:	Lectures Examples Private study	20h 12h 78h

Lecturers: M. Discacciati, R. Codina

Contents:

This module presents the fundamentals of finite element methods in flow problems. Emphasis is given to stabilized methods and time integration. The presentation covers both the essential theoretical aspects as well as hands-on applications. In particular, specific techniques for Euler and Navier-Stokes flows are presented and discussed.

1. Conservation equations
2. Stabilization of the steady convection equation
3. Time integration of the unsteady transport equation
4. Compressible flow
5. Unsteady convection-diffusion problems
6. Viscous incompressible flows
7. Modeling turbulence
8. Advanced topics

Intended Learning outcomes: to demonstrate

a knowledge and understanding of:	the fundamentals of the behaviour and numerical approximation of the fluid dynamics equations; spatial and temporal discretizations and relevant mathematical aspects; stabilization of convection and incompressibility.
an ability to: (thinking skills)	understand and identify the key issues relevant to discretization both in space and time; set up appropriate initial and boundary conditions; identify the proper methods for the corresponding problem.
an ability to: (practical skills)	implement and use computer programs to solve fluid dynamics problems; use any one programming language to develop computer codes; use mesh generators to produce appropriate meshes for analysis; use post-processing software and produce graphical representation of results
an ability to: (key skills)	study independently; use library resources; submit the projects in time; produce project reports and present them.

Assessment: 50% continuous assessment assignments, 50% from end of Term examination (50% open-book).

Practical Work: Exercises will be set, which will involve coding some of the presented methods.

Recommended texts: Lecture notes

Donea, J., Huerta, A., *Finite Element Methods for Flow Problems*, Wiley, 2003

PRACTICAL TRAINING

Credits: 15 **Semester:** 1&2 **Compulsory:** Yes

Pre-requisite modules:

Co-requisite modules:

Incompatible modules:

Format: Lectures 0
Example classes 0
Directed private study 300h

Lecturer: Various

Assessment: Continuous assessment

Module content:

The aim of the module is to give students an opportunity to apply their skills and knowledge in computational mechanics in an industrial context. Students will be placed within companies or research organizations with an interest in computational mechanics to carry out an agreed practical project which will be assessed by means of a final written report.

Students will be placed in engineering industries, consultancies or research institutions that have an interest ad expertise in computational mechanics and will carry out an agreed practical project either during a single continuous placement of 7 weeks or via an equivalent series of shorter visits. The nature of the project will very much depend on the placement but can involve structural mechanics,solid mechanics, fluid mechanics or hydrodynamics. Typically, students will be trained by the relevant industry in the use of their in-house or commercial computational mechanics software. The outcome of this project will be a report and a presentation to be completed before the end of May. The report and presentation will be assessed by two internal examiners who will also consider a formal written report submitted by the industrial supervisor.

Practical work:

Intended Learning Outcomes:

At the end of the module students should have gained expertise on the application of computational mechanics in an industrial context. The project should allow them to appreciate the practical aspects of computational mechanics and the way in which is being used in industry to solve real engineering problems. Students will gain knowledge and expertise on the use of the particular range of commercial software used in the industry were they are placed. At the end of the module students should be capable of writing a comprehensive technical report on the work developed and present it to a small audience.

Recommended texts: As directed by supervisor

Further reading:

Additional notes:

Swansea University

MSc modules distribution

3th & 4th Semester Swansea University

(60 ECTS)

Structural Engineering Elective Modules	**ECTS (Term1)**	**ECTS (Term2)**
Dynamics of Structures	5	
Computational Plasticity		5
Advanced Structural Analysis	5	
Nonlinear Continuum Mechanics		5
Fluid Mechanics Elective Modules	**ECTS (Term1)**	**ECTS (Term2)**
Computational Fluid Dynamics		5
Reservoir Modelling and Simulation		5
Fluid Structure Interaction		5
Transversal modules (5 compulsory ECTS)	**ECTS (Term1)**	**ECTS (Term2)**
Communication skills for research engineers	5	
Master Thesis (compulsory)	**ECTS (Term1)**	**ECTS (Term2)**
Case Study(*)	10	
Supervised MSc thesis(*)	15	15

(*) A supervisor will be appointed for each candidate who will be responsible for ensuring that studies are carried out in line with the Institution's good practice guidelines. At the end of the semester each candidate must submit his dissertation to the exam coordinator in the format prescribed by the Consortium Board of Studies. A defense will be organized. The dissertation will be examined by both an internal examiner (who will not be the student's supervisor) and an external examiner (who may be a member of staff from another Institution within the Consortium).

COMMUNICATION SKILLS FOR RESEARCH ENGINEERS		
Credits: 5 **Semester:** 1 **Compulsory**: YES		
Format :	Lectures Examples Private study	15h 15h 95h
Lecturers: M. Cross		
Contents: 1. Written Communication: Reports, Theses, Journal & Conference papers [6] 2. Oral Communication: Research Presentations, Attending conferences & presenting papers. [6] 3. Role Play: Attending & chairing meetings, Job interviews. [3]		
Intended Learning Outcomes: to demonstrate		
a knowledge and understanding of:	Methods of delivery of oral presentations. Logical structure of scientific texts (including standards of referencing).	
an ability to: (thinking skills)	Identify key aspects of research work for preparation of effective research presentations/papers.	
an ability to: (practical skills)	Use computer software to prepare reports/presentations.	
an ability to: (key skills)	Produce work to a deadline. Summarise and organise complex ideas in order to present them clearly within a given time and in accordance with the level of understanding of the audience. Effectively take part in meetings.	
Assessment: Written report (50%), Oral presentation (50%).		
Recommended texts: Module Overheads Set.		

DYNAMICS OF STRUCTURES

Credits: 5 **Semester:** 2 **Compulsory**: NO

Format :	Lectures Examples Private study	22h 11h 92h

Lecturers: Y. Feng

Contents:

1. **Introduction:** Dynamic effects on structure, design issues. [1]
2. **Single Degree of Freedom Problems:** the SDOF spring-mass system, equivalent SDOF structures – energy method, analytical solution of SDOF problems, step by step solution methods, earthquake loading, response and design spectra, Eurocode- 8 inelastic spectrum. [12]
3. **Multiple Degree of Freedom Problems:** natural modes and frequencies of vibration, modal decomposition, reduction and iterative methods, earthquake loading, shear building model, design considerations. [6]
4. **Distributed Mass Systems:** vibration of rods, transversal vibration of beams and plates, 3-D elastic waves, finite element discretization. [2]
5. Revision [1]

Intended Learning Outcomes: to demonstrate

a knowledge and understanding of:	Basic dynamic concepts of SDOF systems such as dynamic magnification, resonance, damping. The Rayleigh method for the simplification of complex structures to a SDOF system. Earthquake response and design spectra. Analytical and step-by-step integration methods for impulse and periodic forces. Modes of vibration and modal decomposition. Reduction methods. Mass damping. The shear building simplified model.
an ability to: (thinking skills)	Determine Rayleigh vibration shape functions for simple structures. Distinguished between stiffness/mass/damping dominated problems. Identify dynamic loading on bridges, footbridges, floors, etc. resulting from moving loads or rhythmic activities. Identify the correct solution process for different loads. Identify correct earthquake design spectrum following Eurocode-8. Identify adequate problem reduction strategies for MDOF problems.
an ability to: (practical skills)	Evaluate equivalent stiffness, mass parameters and natural frequency of vibration for simple structures using the Rayleigh method. Use Excel spreadsheets to integrate step-by-step SDOF structures under complex loading. Use earthquake design spectra. Tune a mass damper. Use the simple shear building model to evaluate earthquake design forces on simple buildings. Combine peak responses from different modes.
an ability to: (key skills)	Problem solving. Use a personal computer, in particular Excel. Study independently and use library resources. Effectively take notes and manage working time.

Assessment: Written, open book, examination (2 hrs) at the end of Semester 2 accounts for 75% of the marks, the remainder are awarded to an individual project, for which students are expected to solve a dynamical problem using Excel and write a technical report on their findings.

Penalty for late submission of course work is Zero mark in the course work.

Practical work: Individual projects allocated during the module.

Recommended texts: Chopra, *Dynamics of Structures*, Prentice Hall
Clough & Penzien, *Dynamics of Structures*, McGraw-Hill
ICE (Design and Practice Guides), *Dynamics - An Introduction for Civil & Engineers*

ADVANCED STRUCTURAL ANALYSIS

Credits: 5 **Semester:** 2 **Compulsory**: NO

Format :	Lectures Examples Private study	20h 10h 95h

Lecturers: E. de Souza Neto

Contents:

1. Introduction to the flexural behaviour of plates. Equilibrium conditions and the development of the governing equation for plate bending in terms of bending moments. [2]
2. Compatibility conditions. Constitutive laws and the moment/curvature relations. The governing equation in terms of displacements. [2]
3. Boundary conditions for rectangular plates. Navier's solution for simply supported rectangular plates. [2]
4. Point loaded simply supported rectangular plates. Development of the governing equations for axisymmetrically loaded circular plates. [2]
5. Solution of axisymmetrically loaded circular plate problems. Introduction to the limit analysis of reinforced concrete slabs. [2]
6. Principle of virtual work method and equilibrium method for the evaluation of limit loads of slabs. Problem solution involving orthotropically reinforced slabs. [2]
7. Introduction to shell behaviour. The theory of shell action under membrane behaviour. [2]
8. The solution of a range of engineering problems involving axisymmetrically loaded shells of revolution. [2]
9. Theory of unsymmetrically loaded shells of revolution. Solution of engineering examples. [2]
10. Introduction to prestressed concrete. Uniformly prestressed sections – theory and numerical examples. [2]
11. Eccentrically prestressed sections – theory and numerical examples. Statically indeterminate systems. Evaluation of concordant tendon profiles. [2]
12. Revision. [2]

Intended Learning outcomes: to demonstrate

a knowledge and understanding of:	The principles of equilibrium, compatibility and the influence of material behaviour. Virtual Work expressions of equilibrium and compatibility and the Unit Load Theorem.
an ability to: (thinking skills)	Identify the forces applied by various supports. Distinguish between axial, bending, shear and torsional load carrying actions. Distinguish between statically determinate and indeterminate structures. Identify appropriate methods of analysis for trusses, beams and frames.
an ability to: (practical skills)	Apply the equations of static equilibrium to calculate reactions, axial forces, bending moments, shear forces and torsional forces. Use the Unit Load Method for the calculation of displacements and rotations in structures. Analyse simple externally indeterminate 2-dimensional structures. Apply the Moment Distribution Method to the analysis of statically indeterminate beams. Use a computer to model and analyse trusses, beams and frames..
an ability to: (key skills)	Use a personal computer. Study independently and use library resources. Effectively take notes and manage working time.

Assessment: 100% from end of Semester closed book examination.

Recommended texts: *Structures - Theory and Analysis* by M.S. Williams & J. D. Todd, Macmillan Press, 2000, ISBN 0-333-67760-9. (This covers Level 2 and Level 3 material)
Further Reading: Coutie, Coates and Kong, *Structural Analysis*, 1998, 3rd Edition, VNR.

FLUID-STRUCTURE INTERACTION	
Credits: 5 **Semester:** 2 **Compulsory**: NO	
Format : Lectures Example classes/Tutorials Directed private study	
Lecturer: WG. Dettmer	
Assessment: course work (40%), written examination (60%)	
Module content: [lecture hours] • **Fluid-Structure Interaction and Classical Aeroelasticity** [12] aerodynamic forces, lift curves, drag polars, static problems, vortex induced vibration, lock-in, galloping, flutter, various applications • **Solution Strategies for Coupled Problems** [8] model problem, monolithic and partitioned schemes, weak and strong coupling, staggered schemes, iterative strategies, relaxation, inexact and exact block Newton-Raphson methods • **Numerical Modelling of Fluid-Structure Interaction** [10] review of basics of numerical modelling of fluid flow and structural dynamics, interface tracking/capturing, fluid flow on moving domains, interface modelling, introduction to in-house computer programme, example problems	
Practical work: some analytical solutions, analysis of the model problem, solution of selected problems with the in-house computer programme.	
Intended Learning Outcomes: After completing this module you should be able to demonstrate:	
a knowledge and understanding of:	different phenomena of fluid-structure interaction, different solution strategies for coupled problems, difficulties associated with the numerical modelling of fluid-structure interaction
an ability to: (thinking skills)	predict qualitatively the behaviour and the likeliness of instabilities of an aeroelastic system, formulate solution procedures for systems of coupled nonlinear equations
an ability to: (practical skills)	calculate estimates of the frequency and amplitude of flow-induced structural oscillations, calculate estimates of the critical fluid velocity in aeroelastic stability problems, write computer programmes for the solution of systems of coupled nonlinear equations, simulate fluid-structure interaction problems with the in-house code
an ability to: (key skills)	study independently, use library resources, effectively take notes and manage working time
Recommended texts: R. D. Blevins, *Flow Induced Vibration*, Van Nostrand Reinhold Company, New York, 1977 or other editions, selected scientific papers, lecture notes	
Further Reading:	
Additional notes: **none**	

Universitat Politècnica de Catalunya/ CIMNE

MSc modules distribution

3rd & 4th Semester UPC/CIMNE

(60 ECTS)

Solid Mechanics Elective Modules	**ECTS**
Computational Mechanics Tools *	5
Multiscale Computational Mechanics * Coupled problems	5
Advanced Discretization Methods *	5
Fluid Mechanics Elective Modules	
Computational Wave Propagation *	5
Programming for Engineers and Scientists	5
Transversal modules (5 compulsory ECTS)	5
Master Thesis (compulsory)	**ECTS (Term2)**
Supervised MSc thesis(*)	30

(*) A supervisor will be appointed for each candidate who will be responsible for ensuring that studies are carried out in line with the Institution's good practice guidelines. At the end of the semester each candidate must submit his dissertation to the exam coordinator in the format prescribed by the Consortium Board of Studies. A defense will be organized. The dissertation will be examined by both an internal examiner (who will not be the student's supervisor) and an external examiner (who may be a member of staff from another Institution within the Consortium).

ADVANCED DISCRETIZATION METHODS

Credits: 5	**Semester:** 2	**Compulsory**: NO
Format :	Lectures Examples Private study	25h 15h 95h

Lecturers: A. Huerta, P. Díez, E. Oñate, S. Fernandez-Mendez, S. Idelsohn

Contents:

This module is an extension of the basic concepts included in compulsory modules "Advanced Discretization Methods" and "Finite Element Method". Advanced topics of modern numerical techniques for partial differential equations are presented, with application to a wide variety of problems in science, engineering, and other fields. Topics include Advanced Finite Elements (Discontinuous Galerkin, level sets, X-FEM) and mesh-free methods.

Advanced Finite Elements:

1. Discontinuous Galerkin (DG) for hiperbolic problems. Riemann solvers and numerical fluxes.
2. DG for elliptic operators.
3. Extended finite elements (X-FEM) and applications (crack simulation, holes and inclusions, material interfaces)
4. Level sets.

Mesh-free methods:

5. Overview of mesh-free methods.
6. Moving least squares approximation.
7. Element-free Galerkin method.
8. Smooth particle hydrodynamics.
9. Implementation of essential boundary conditions.
10. Coupling of finite elements and mesh-free methods.
11. Particle finite element methods
12. Discrete element methods
13. Overview of method and applications.
14. Basic formulation.

Intended Learning Outcomes: to demonstrate:

A knowledge and understanding of:	Modern numerical techniques for the discretization of boundary value problems and its range of applicability
an ability to: (thinking skills)	Understand and formulate efficient numerical procedures and solve illustrative problems; identify the proper methods for the corresponding boundary value problem.
an ability to: (practical skills)	Understand practical implications of behaviour of numerical methods and solutions; logically formulate numerical methods for solution by computer with a programming language
an ability to: (key skills)	Study independently; use library resources; use a personal computer for basic programming; effectively take notes and manage working time.

Assessment: 50% continuous assessment assignments, 50% from end of Semester examination (50% open-book).

Practical Work: Exercises will be set, which will involve coding some of the presented methods.

Recommended texts: Lecture notes

Erwin Stein, René De Borst and Thomas J.R. Hughes (Editors), *Encyclopedia of Computational Mechanics*, Wiley, 2004 (Volume 1 Chapter 10, Volume 3 Chapter 4)

S. Mohammadi, *Discontinuum Mechanics Using Finite and Discrete Elements*, WITPress, Southampton, 2003

COMPUTATIONAL WAVE PROPAGATION

Credits: 5 **Semester:** 2 **Compulsory**: YES

Format :	Lectures Examples Private study	25h 15h 95h

Lecturers: A. Rodríguez, S. Fernandez-Mendez, J. Mora

Contents:

This module introduces basic concepts of wave theory and focuses on computational strategies to simulate the propagation of linear waves in the context of various engineering applications.
Basic Theory:

1. Sample physical origins of wave motion: sound in pipe, elastic rod, blood flow
2. Introduction to wave propagation via 1D problems.
3. Elastodynamic theory in 3D.
4. Integral representations and integral equations.
5. Electromagnetics.
6. Acoustics and vibroacoustics.
7. Characteristics and Riemann problems for linear hyperbolic equations

Numerical methods for wave propagation:

8. Boundary Element Method (BEM).
9. Domain based methods: Finite Differences, Finite Volumes and Discontinuous Galerkin:
   a. General formulation for conservation laws
   b. Numerical flux: upwind methods, Godunov's and Roe's methods
   c. High-resolution methods: Flux and TVD limiters
   d. Convergence, accuracy and stability
10. Boundary conditions on artificial boundaries

Intended Learning Outcomes: to demonstrate

a knowledge and understanding of:	The fundamentals of the behaviour and numerical approximation of wave propagation problems; basic concepts of wave theory; overview of computational strategies to simulate the propagation of waves.
an ability to: (thinking skills)	Understand and identify the key issues relevant to the discretization of wave propagation problems; identify the appropriate solution methods for each type of problem.;
an ability to: (practical skills)	Implement and use computer programmes to solve wave propagation problems; implement and use different solution methods; critically analyze the results of computer programmes.
an ability to: (key skills)	Study independently; use library resources; submit the projects in time; produce project reports and present them.

Assessment: 50% continuous assessment assignments, 50% from end of Semester examination (50% open-book).

Practical Work: Exercises will be set, which will involve coding some of the presented methods.

Recommended texts: Lecture notes

Further readings R.J. LeVeque, *Finite Volume Methods for Hyperbolic Problems*, Cambridge Univ. Press, 2002
A. Taflove, *Computational Electrodynamics: The Finite-Difference Time-Domain Method*, Artech House, 1995
J. D. Achenbach, *Wave Propagation in Elastic Solids*, North Holland Publ. Co., 1973.
J. Domínguez, *Boundary Elements in Dynamics*, Computational Mechanics Publications, Elsevier, UK, 1993.
Jianming Jin, *The Finite Element Method in Electromagnetics*, John Wiley & Sons, 1993

MULTISCALE COMPUTATIONAL MECHANICS		
Credits: 5	**Semester:** 2	**Compulsory**: NO
Format :	Lectures Examples Private study	25h 18h 70h
Lecturers: M. Arroyo, A. Rodriguez-Ferran		

Contents:

This module will focus on computational solid mechanics with full nonlinear kinematics. For the sake of clarity, the main emphasis will be on hyperelastostatics, although the framework for general constitutive relations and hints on finite deformation inelasticity will be provided. An introduction to the microstuctural and atomistic foundations of constitutive theory will be presented, as well as an overview of modern multi-scale approaches to material modeling. The duality of finite deformation solid mechanics and shape and microstructure optimization through the theory of the material or configurational equilibrium will be presented to broaden the scope of the module. In addition to quasistatic equilibrium problems, the module will provide a brief account on time integration in finite kinematics solid dynamics.

Intended Learning Outcomes: to demonstrate

A knowledge and understanding of:	The formulation and discretization of solid mechanics problems with full nonlinear kinematics, and the solution of the resulting equations; basic constitutive theory, as well as micro-structure and physical foundations.
an ability to: (thinking skills)	Understand physically and mathematically finite deformation elasticity and its discretization; make the connection with optimization; understand the physical underpinnings of constitutive theory to critically use constitutive models.
an ability to: (practical skills)	Implement and use computer programmes to solve nonlinear solid mechanics problems; use and implement different solution methods and constitutive models; critically analyze the results of computer programmes.
an ability to: (key skills)	Study independently; use library resources; submit the projects in time; produce project reports and present them.

Assessment: 50% continuous assessment assignments, 50% from end of Semester examination (50% open-book).

Practical Work: Exercises will be set, which will involve coding some of the presented methods.

Recommended Texts: Lecture notes

Bonet, Wood, *Nonlinear Continuum Mechanics for Finite Element Analysis* , Cambridge, 1997

Belytschko, Liu, Moran, *Nonlinear Finite Elements for Continua and Structures*, Wiley 2000

COMPUTATIONAL MECHANICS TOOLS

Credits: 5 **Semester:** 2 **Compulsory**: NO

Format :	Lectures Examples Private study	25h 15h 95h

Lecturers: Y. Shen, I. Arias, N. Pastor

Contents:

This module presents an introduction to the first and last step of a numerical simulation in computational mechanics. That is, it presents the numerical techniques involved in the pre and post processing steps On one hand, the principal techniques that allow building a computational mesh from a CAD model are presented. On the other hand, numerical techniques for the visualization of discrete fields defined on a computational grid are discussed. These techniques are introduced solving practical applications using Gid (an existing commercial package).

1. Geometry representation
2. Meshing algorithms overview
3. Structured mesh generation
4. Triangular and tetrahedral mesh generation
5. Quadrilateral and hexahedral mesh generation
6. Mesh quality improvement
7. Fundamentals of scientific visualization
8. Techniques for discrete field representation

Intended Learning Outcomes: to demonstrate

a knowledge and understanding of:	the basic steps of the mesh generation process; the advantages and drawbacks of the most used mesh generation algorithms; the fundamentals of scientific visualization.
an ability to: (thinking skills)	identify several source of problems of a given CAD representation; set up the model attributes to build a mesh; select the proper visualization technique for the corresponding result.
an ability to: (practical skills)	to generate a finite element model from a CAD model using several GiD; to visualize the numerical results of a finite element simulation using GiD.
an ability to: (key skills)	study independently; use library resources; submit the projects in time; produce project reports and present them.

Assessment: 100% continuous assessment assignments.

Practical Work: Exercises will be set, which will involve coding some of the presented techniques and using several commercial packages.

Recommended texts: Lecture notes

Further Readings

Faux D. and Pratt M.J. *Computational Geometry for Design and Manufacture*, Elli Horwood Publishers, 1987.

Thompson J.F., Soni B.K., and Weatherill N.P, *Handbook of Grid Generation*, CRC Press, 1999

Schroeder W., Martin K., Lorensen B.,*The Visualization Toolkit An Object-Oriented Approach To 3D Graphics*, Kitware, Inc, 2002

PROGRAMMING FOR ENGINEERS AND SCIENTISTS

Credits: 5 **Semester:** 1 **Compulsory**: NO

Format :	Lectures	12h
	Examples	20h
	Private study	70h

Lecturers: S. Zlotnik

Contents:

The purpose of this module is to introduce the basis of the scientific programming. These fundamental programming skills will be acquired using MATLAB. However, the basic concepts may be extended to any other high level programming language. At the end of the module graduates have acquired elementary programming skills in a high-level programming language. Moreover, they have learned to write computer programmes that allow them to implement the algorithms needed to solve problems in their own area of science or engineering.

1. Introduction to MATLAB: components and environment.
2. Numbers, variables, operators and functions
3. Arrays and matrices
4. Plotting curves and surfaces
5. Loops and decisions
6. Simple input/output facilities
7. Advanced topics: MATLAB tools and profiling

Intended Learning Outcomes: to demonstrate

A knowledge and understanding of:	The key issues of object-oriented programming in scientific and engineering applications; C++ language features to implement object-oriented concepts; the advanced and modern techniques of code improvement and optimization.
an ability to: (thinking skills)	Develop an structured programming approach to solve scientific problems; recognize the MATLAB features that allow to implement a given algorithm..
an ability to: (practical skills)	Implement and develop MATLAB codes to solve problems in a scientific or engineering environment; generate a graphic representation of a given set of data; optimize the performance of an existing MATLAB code using the profiler.
an ability to: (key skills)	Study independently; use library resources; use computational resources, submit the projects in time; produce project reports and present them.

Assessment: 100% continuous assessment assignments.

Practical Work: Exercises will be set, which will involve coding and analyzing some of the presented programming techniques.

Recommended texts: Lecture notes

Recktenwald, G. W., *Numerical Methods with MATLAB: Implementations and Applications*, Prentice Hall, 2000

Nakamura S. *Numerical Analysis and Graphic Visualization with MATLAB,* Prentice Hall, 1996

Ecole Centrale de Nantes
MSc modules distribution

3th Semester

Students following the 3rd semester in Nantes have to take six compulsory modules for a total of 23 ECTS.
Student have to choose two electives modules for an amount of 7 ECTS, one 4 ECTS module and one 3 ECTS module.

Compulsory Modules : 18 ECTS	Total ECTS
Computational methods for incompressible flows	4
Extended finite element method and level set techniques	3
Model reduction	4
Numerical methods for simulation of coupled problems	4
Physical modeling of fluids	3
Transversal modules: 5 ECTS	
Business Environment	2
French Language	3
Elective Modules (subject to timetable constraints and availability) : 7 ECTS	
Computational damage and fracture mechanics for polymers and composites	3
Domain decomposition and iterative solvers	4
Fluid-structure interaction and advanced CFD	3
Materials modeling for numerical simulations	4
Multi-scale numerical methods	3
Numerical methods for uncertainty quantification	4

4th Semester

Master Thesis	30 ECTS

The 4th semester is dedicated to the master thesis. A supervisor will be appointed for each candidate who will be responsible for ensuring that studies are carried out in line with the Institution's good practice guidelines. At the end of the semester each candidate must submit his dissertation to the exam coordinator in the format prescribed by the Consortium Board of Studies. A defense will be organized. The dissertation will be examined by both an internal examiner (who will not be the student's supervisor) and an external examiner (who may be a member of staff from another Institution within the Consortium).

BUSINESS ENVIRONMENT

Credits: 2 **Semester:** 1 **Compulsory**: YES

Format :	**Lectures**	5h
	Examples	20h
	Private study	25h

Lecturers: Christine Evain

Contents:

High-tech industries are driven by new ways of thinking because of many recent changes in business environments. These changes include market internationalization, growth of high technology sectors, corporate merging and acquisition trends, industrial and production re-organization, globalization and specialization with major high tech company subcontracting to small and medium-sized businesses. This class aims to explain market evolutions and to provide insight into new business practices and strategic decision making in competitive fields.

The course is based on many practical exercises, from thematic conference organization to situational role plays which includes a wide range of commercial negotiation ideas. The students are encouraged to improve their language skills through critical analysis of recent documents from the Internet (the international press, conferences or audiovisual material).

Intended Learning Outcomes: to demonstrate

A knowledge and understanding of:	Business relationship and growth strategies in high technology sectors.
an ability to: (thinking skills)	Understand present and future evolution of high-tech sectors.
an ability to: (practical skills)	Take part in business negotiation around innovative projects. Critical analysis of strategic decision processes
an ability to: (key skills)	Study independently and take part in group reflection, communication skills.

Assessment: Continuous assessment

Recommended texts: Lecture notes and slides.

COMPUTATIONAL METHODS FOR INCOMPRESSIBLE FLOWS

Credits: 4 **Semester:** 1 **Compulsory**: YES

Format :	**Lectures** **Examples** **Private study**	14h 6h 80h

Lecturers: M. Visonneau

Contents:

This module presents the modeling strategies which are used to compute viscous incompressible flows by solving the Reynolds-Averaged Navier-Stokes Equations.

It covers mainly :

- a description of the fully unstructured finite volume discretization strategies
- a study of the coupling strategies to account for the incompressibility constraint and various pressure velocity coupling algorithms
- a description of a general face-based unstructured finite volume discretization
- a critical review of various applications ranging from shape optimization for ship hulls or wings and optimal flow control in aerodynamics

Intended Learning Outcomes: to demonstrate

A knowledge and understanding of:	The basic elements needed to build a reliable numerical and physical modeling strategy for incompressible flow.
an ability to: (thinking skills)	Understand the basic properties which must be fulfilled by the modeling strategies at continuous and discrete levels.
an ability to: (practical skills)	Understand the limitations and requirements of discretization methods needed to solve RANSE for high Reynolds flows around complex geometries.
an ability to: (key skills)	Study independently; use library resources; use a personal computer for basic programming; effectively take notes and manage working time.

Assessment: 100% from end of Semester examination.

Practical Work: Small scale CFD projects will be proposed through the use of ISIS CFD code developed by the CFD research team.

Recommended texts: Lecture notes

Peric and J. Ferziger., *Computational Methods for Fluid Dynamics*, Springer Verlag, 2002

C. Hirsch, *Numerical Computation of Internal and External Flows (Second Edition)*, Elsevier, 2007

Further Readings:

Peyret R., *Handbook of Computational Fluid Mechanics*, Academic Press, 1996

Marnet-CFD Best Practice Guidelines for Marine Applications of CFD :
https://pronet.wsatkins.co.uk/marnet/guidelines/guide.html

EXTENDED FINITE ELEMENT METHOD AND LEVEL SET TECHNIQUES

Credits: 3 **Semester:** 2 **Compulsory**: YES

Format :	**Lectures**	14h
	Examples	12h
	Private study	50h

Lecturers: N. Moës and N. Chevaugeon

Contents:

The course presents an extension of the finite element method baptized, X-FEM, which is currently widely used in research and starts to appear in Industry. This method basically eliminates the need to mesh physical surfaces (cracks, holes, material interfaces,) in finite element computations. The surfaces are located and evolved by the level set technique which is also taught in the course. The topics are organized as follows :

- Overview of a wide class of problems that cannot be solved efficiently by the finite element method and necessity to extend the method.
- The keystones of the extended Finite Element Method: enrichment with the partition of unity and level set representation of surfaces.
- Detailed approach to model surfaces of discontinuity in a field, a derivative of a field and in the matter for linear static problems.
- Industrial applications in fracture mechanics.
- Level sets and fast marching algorithms to evolve surfaces.
- More advanced topics with X-FEM: Large deformation, Contact and Explicit Dynamics.

Intended Learning Outcomes: to demonstrate

A knowledge and understanding of:	The current difficulties encountered by the finite element method; the partition of unity to model surfaces for linear and nonlinear problems; the level set technique to evolve surfaces; basic knowledge of nonlinear finite elements for static and dynamics.
an ability to: (thinking skills)	Identify the need for extended finite elements and level sets in problems taken for different areas of mechanics.
an ability to: (practical skills)	Logically formulate a numerical approach using extended finite elements and level sets for different practical problems and translate the formulation to an existing extended finite element code
an ability to: (key skills)	Study independently; use library resources; use an existing extended finite element code; effectively take notes and manage working time.

Assessment: 50% project work, 50% from end of semester examination (open book)

Practical Work:

- Exercises will be set, which will involve the use of an existing software.
- Understand and explain a research paper on the topic.

Recommended texts: Lecture notes

A dozen recent research papers in English on X-FEM and level sets.

Further Readings:

Osher, S., Fedkiw, R., *Level Set Methods and Dynamic Implicit Surfaces,* Springer, 2003.

FRENCH LANGUAGE

Credits: 5 **Semester:** 1 **Compulsory**: YES

Format :	**Lectures**	25h
	Examples	25h
	Private study	75h

Lecturers: F. Dorel

Contents:

To allow students to learn general French, to develop language skills of oral and written comprehension and expression. After completing this course, the students will be able to communicate in spoken and written french, in a simple but clear manner on familiar topics in the context of study, hobbies etc.

Another important goal of this course is to introduce to french culture. At the end of course (120 hours), the complete beginners can achieve the level A1 and some aspects of A2 of The Common European Framework of Reference for Languages**.** More advanced students may aim the levels B1/B2.

Intended Learning Outcomes:

Be able to hold a simple conversation

Acquire a vocabulary of approximately 2000 words

Gain an understanding of basic grammar and reading/writing.

Recommended texts: Lecture notes.
French dictionary.

MODEL REDUCTION

Credits: 4 **Semester:** 1 **Compulsory**: YES

Format :	**Lectures** **Examples** **Private study**	12h 8h 80h

Lecturers: F. Chinesta

Contents:

Numerous models encountered in science and engineering remain nowadays, despite the impressive progresses attained recently in computational simulation techniques, intractable when the usual and well experienced discretization techniques are applied for their numerical simulation. Model reduction allows spectacular simulation speed-up, of several orders, and also solving models never until now solved (3D models involving extremely small time steps and models suffering the so-called curse of dimensionality). The topics are organized as follows :

- Model reduction techniques based on the use of the Proper Orthogonal Decomposition;
- Towards an adaptive reduced approximation basis;
- Reduced modeling and parallel time integration;
- Coupling FEM and reduced modeling: treatment of fixed and moving interfaces;
- The Proper Generalized Decomposition (PGD);
- Applications in computational science and engineering;

Intended Learning outcomes: to demonstrate

A knowledge and understanding of:	the current difficulties encountered by standard incremental and mesh based simulation techniques; proper orthogonal decomposition; separated representations for circumventing curse of dimensionality;
an ability to: (thinking skills)	identify the need for models reduction in problems taken for different areas of computational science and engineering.
an ability to: (practical skills)	formulate reduced models for different kind of models identified in many areas: computational biology, computational mechanics, forming processes simulation, …
an ability to: (key skills)	study independently; use library resources; develop simulations codes making use of model reduction; effectively take notes and manage working time.

Assessment: 50% project work, 50% from end of semester examination (open book)

Practical Work:

1. Exercises will be set, which will involve the development of appropriate simple software.
2. Understand and explain a research paper on the topic.

Recommended texts: Lecture notes

A dozen recent research papers in English on model reduction.

NUMERICAL METHODS FOR SIMULATION OF COUPLED SYSTEMS

Credits: 4 **Semester:** 1 **Compulsory**: YES

Format :	**Lectures** **Examples** **Private study**	12h 8h 80h

Lecturers: L. Stainier

Contents:

The course will present and discuss various computational approaches for the numerical simulation of coupled problems. The first part of the course will consider the problem from the abstract point of view of coupled systems. We will identify and describe

- the various classes of coupled problems (weak vs. strong coupling),
- the various classes of algorithmic approaches (monolithic, staggered, sequential),
- the problems and difficulties linked to field transfer.

In the second part of the course, these concepts will be put in practice for a specific type of coupled problem. In particular, we will treat thermo-mechanical problems. The different potential sources of coupling will be reviewed, as well as their implication from the computational point of view. The different algorithmic approaches will then be put in practice in the project work for various thermo-mechanical problems (thermo-plasticity, thermo-visco-elasticity, shape memory alloys, …).

Intended Learning outcomes: to demonstrate

A knowledge and understanding of:	the challenges in numerical simulation of coupled problems, the broad classes of coupled problems, the different algorithmic approaches which are used in practice, their relative advantages and associated difficulties ;
an ability to: (thinking skills)	identify and classify coupled problems of various types, identify sources and mechanisms of coupling and their implication from a computational point of view ;
an ability to: (practical skills)	logically formulate an adapted algorithmic strategy for different practical coupled problems and translate the formulation to a practical computational approach using as much as possible existing tools ;
an ability to: (key skills)	study independently; use library resources; solve coupled problems with existing finite element code(s); effectively take notes and manage working time.

Assessment: 100% project work

Project Work: the project will consist in a short bibliographic study of a given coupled problem, followed by the implementation of a numerical tool able to numerically solve this problem. The numerical tool will be implemented either within Matlab or with Python hooks to existing software.

Recommended texts:

A selection of recent research papers on computational strategies for coupled problems will be used in the course.
A good starting point is the following paper :
"Partitioned analysis of coupled mechanical systems", C.A. Felippa, K.C. Park, C. Farhat, Comput. Methods Appl. Mech. Engrg. 190, 3247-3270, 2001.

PHYSICAL MODELING OF FLUIDS

Credits: 3	**Semester:** 1	**Compulsory**: YES
Format :	**Lectures** **Examples** **Private study**	15h 5h 55h

Lecturers: M. Visonneau and A. Leroyer

Contents:

This module is devoted to the analysis of the main physical modeling strategies used to compute viscous incompressible flows. It covers:
(i) an overview of the main turbulence closures used in high Reynolds incompressible flows ranging from statistical closures to Large Eddy Simulation models,
(ii) a review of the most recent cavitation models and an analysis of the underlying physics,
(iii) a critical illustration of the predictive capabilities of these models for various experimental data bases

Intended Learning Outcomes: to demonstrate

A knowledge and understanding of:	the fundamentals of physical models : turbulences, cavitation the limitations of the physical models the evolution of the physical models with respect to the computational power
an ability to: (thinking skills)	chose an appropriate physical model for a given problem
an ability to: (practical skills)	use properly a CFD solver for standard physical configurations; analyse and review the numerical results
an ability to: (key skills)	study independently; manage an numerical project on a computer

Assessment: 100% from numerical project report

Recommended texts: Lecture notes.
D.C. Wilcox, *Turbulence Modelling for CFD, DCW Industrie, 2002*
C. Hirsch*, Numerical Computation of Internal and External Flows (Second Edition), Elsevier, 2007*

Further Readings:
Marnet-CFD Best Practice Guidelines for Marine Applications of CFD
https://pronet.wsatkins.co.uk/marnet/guidelines/guide.html

COMPUTATIONAL DAMAGE AND FRACTURE MECHANICS FOR POLYMERS AND COMPOSITES

Credits: 3 **Semester:** 1 **Compulsory**: NO

Format :	**Lectures** **Examples** **Private study**	15h 5h 55h

Lecturers: L. Gornet and E. Verron

Contents:

This module presents the fundamentals of mechanical response, damage and fracture of polymers and composites as applied to design. The emphasize is laid on the continuum mechanics description and computational aspects.

Topics:

- Overview of polymers and reinforced composites: basic chemistry and microstructure, mechanical response, testing methods,
- Constitutive models for engineering applications: formulation and numerical implementation
  - composites: anisotropic linear elasticity, yield criteria, damage models, application to naval architecture,
  - polymers: large strain rubber-like elasticity and viscoelasticity, stress-softening, application to automotive rubber parts.
- Fracture and fatigue: Linear fracture mechanics: Griffith crack theory, stress intensity factors, J integral, Specific numerical methods,
  - Extension to non-linear elasticity and inelasticity,
  - Fatigue life prediction.

Intended Learning Outcomes: to demonstrate

a knowledge and understanding of:	The basic elements of microstructure of polymers and composites; relevant constitutive models for engineering applications; basics of fracture theory; finite element implementation and numerical simulation of structural responses including fracture and fatigue life prediction.
an ability to: (thinking skills)	Understand and formulate basic models and numerical simulations.
an ability to: (practical skills)	Design non-metallic engineering structures and predict their mechanical response. Analyze and perform the corresponding computations.
an ability to: (key skills)	Study independently, use library resources, use existing commercial finite element code.

Assessment: 50% continuous assessment assignments, 50% from end of Semester examination.

Practical Work: Exercises will be set, which will involve finite element tutorials.

Recommended texts: Lecture notes

Herakovich, C. T., *Mechanics of Fibrous Composites*, John Wiley & Sons, 1998

Holzapfel G., *Nonlinear Solid Mechanics. A Continuum Approach for Engineering*, John Wiley & Sons, 2000

Further Readings:

Ward, I. M.; Sweeney, J., *Introduction to the Mechanical Properties of Solid Polymers,* 2nd Edition, John Wiley & Sons, 2004

Gdoutos E. E., *Fracture Mechanics. An Introduction,* 2nd Edition, Springer, 2005

DOMAIN DECOMPOSITION AND ITERATIVE SOLVERS

Credits: 4 **Semester:** 1 **Compulsory**: NO

Format :	**Lectures** **Examples** **Private study**	10h 10h 80h

Lecturers: N. Chevaugeon

Contents:

Most numerical methods to solve partial differential equation on large problem end up with the need to solve large linear systems of equations.

This module presents advanced numerical methods for high performance computing and techniques that exploit the specificities of available computational resources in order to solve this problems. The following topics will be addressed:

1. Data structure to store large sparse matrix in a distributed environment.
2. Iterative solvers for large systems of equations and acceleration of convergence (Krylov methods, multigrid preconditioning,…)
3. Domain decomposition methods for PDEs (formulations, mesh partitioning, algorithms)
4. Parallel architectures and computing

Intended Learning Outcomes: to demonstrate

A knowledge and understanding of:	Algorithm and methods to solve large linear system problem on parallel architecture.
an ability to: (thinking skills)	Apply domain decomposition techniques to solve a large problem.
an ability to: (practical skills)	Programing on parallel environment using a message passing library (MPI), construct a domain decomposition using a graph partitioner (METIS).
an ability to: (key skills)	Study independently; use library resources; effectively take notes and manage working time. Use a parallel computer.

Assessment: 50% practical work, 50% from end of Semester examination.

Practical Work: program a parallel iterative solver using domain decomposition.

Recommended texts: Lecture notes

A. Toselli, O. Widlund, *Domain Decomposition Methods - Algorithms and Theory* Springer 2005
Y. Saad, *Iterative methods for sparse linear systems* SIAM 2003

FLUID-STRUCTURE INTERACTION AND ADVANCED CFD

Credits: 3 **Semester:** 1 **Compulsory**: NO

Format :	**Lectures** **Examples** **Private study**	15h 5h 55h

Lecturers: A. Leroyer

Contents:

The goal of this module is to shed light on methodologies used to perform advanced CFD computations. A special focus is dedicated to Fluid-Structure interaction, a topic more and more requested in Industry : the different topics to handle such computations (coupling procedures, mesh deformation,...) are adressed. This module also gets onto other aspects at the cutting edge of CFD, such as error estimation, adaptivity and optimisation. Applications using an industrial solver developed at ECN (FINE^{TM}/Marine) are integrated to this module.

Intended Learning Outcomes: to demonstrate

A knowledge and understanding of:	the fundamentals of fluid-structure interaction: strategies and algorithms of coupling; monolithic vs. partitioned (segregated) approach; ALE formulation; force and displacement transfert. the trends of numerical simulations : optimisation, adaptivity according to the goal of the computation,...
an ability to: (thinking skills)	identify the key issues when performing advanced CFD computations
an ability to: (practical skills)	use the appropriate numerical configuration for a given problem; use a solver (FINE^{TM}/Marine) in practical application examples; analyse and review the numerical results
an ability to: (key skills)	study independently; manage a numerical project on a computer

Assessment: 50% from end of Semester examination, 50% from numerical project report

Recommended texts: Lecture notes.

Peric and J. Ferziger, *Computational Methods for Fluid Dynamics*, Springer Verlag, 2002
E. De Langre, Fluides et Solides, Edition de l'Ecole Polytechnique, 2001

MATERIALS MODELING FOR NUMERICAL SIMULATIONS

Credits: 4 **Semester:** 1 **Compulsory**: NO

Format :	**Lectures** **Examples** **Private study**	15h 15h 70h

Lecturers: A. Poitou and S. Le Corre

Contents:

This course intends to give the basics of non linear materials modeling for both solids and non Newtonian fluids and to illustrate how these behaviors are accounted for in numerical computations

- Overview of basic behaviors in one dimension
- Thermodynamics
- Plasticity of metals, cyclic and isotropic hardening, for infinitesimal deformations. Viscoplasticity, high strain rates.
- Viscoelasticity of fluids
- Integration algorithm for plasticity
- Case study using Abaqus and Comsol multiphysics software

Intended Learning Outcomes: to demonstrate

A knowledge and understanding of:	Fundamentals of thermodynamics of materials and its consequences on materials modeling. Metal plasticity, internal variables, polymer viscoelasticity, induced anisotropy.
an ability to: (thinking skills)	Understand and formulate basic constitutive relations and implement them or simply call them in a Finite Element code.
an ability to: (practical skills)	Understand the physical meaning of most classical constitutive relations for metal plasticity and polymer viscoelasticity. Run and discuss practical case studies involving them.
an ability to: (key skills)	Choose a constitutive relation in a library (Abaqus for example) and run it to for different case studies.

Assessment: 30% continuous assessment assignments, 70% from end of semester examination

Practical Work: Exercises will be set, which will involve using Abaqus and Comsol Multiphysics

Recommended texts:

Simo J.C. and Hughes T.J.R., *Numerical Computational Inelasticity*, Springer, 1997

Lemaître J. and Chaboche J.L., *Mechanics of Solids Materials*, Cambridge University Press,1995

Further Readings:

Jean Lemaitre, *Handbook of Materials Behaviour Models,* Lectures in Mathematics, Academic press 2001

MULTI-SCALE NUMERICAL METHODS

Credits: 3 **Semester:** 1 **Compulsory**: NO

Format :	**Lectures** **Examples** **Private study**	12h 8h 55h

Lecturers: P. Cartraud

Contents:

This course presents classical approaches and recent advances in multi-scale analysis for structural mechanics. These methods allow for an efficient modeling and computation of many modern engineering applications, where complex and highly heterogeneous microstructures are used. The topics include :

- Introduction : presentation of various engineering applications with multiple scales
- Illustrative examples of beams and laminated plates
- Sequential techniques :
  Basic concepts, classical approaches in micromechanics of materials, homogenization of periodic media, numerical implementation, accuracy of the multi-scale solution
- Embedded techniques :
  FE^2 method, Superposition of coarse and fine meshes, use of domain decomposition method
- Overview of other methods (two-scale FEM, GFEM, variational multi-scale method…)

Intended Learning Outcomes: to demonstrate

A knowledge and understanding of:	The limits encountered by 3D detailed models for finely heterogeneous structures; the fundamentals of multi-scale computational approaches; the different steps of sequential techniques; the basic elements of embedded techniques.
an ability to: (thinking skills)	Understand and formulate a multi-scale approach for problems taken from different engineering applications; be able to assess advantages, applicability and limitations of the methods used.
an ability to: (practical skills)	Logically formulate a numerical method using an existing finite element code, perform micro- and macro-scale computations.
an ability to: (key skills)	Study independently; use library resources; use an existing finite element code; effectively take notes and manage working time.

Assessment: 50% technical report, 50% from end of semester examination open book)
Practical Work: bibliography analysis and finite element tutorials.

Recommended Texts:

Zohdi T.I., Wriggers P., *Introduction to Computational Micromechanics*, Springer, 2005
Recent research papers.

Further readings:

Böhm H.J., *A Short Introduction to Basic Aspects of Continuum Micromechanics*, Cdl-fmd report 3-1998, http://ilfb.tuwien.ac.at/links/downloads/cdlfmdrep03.pdf,TU Wien, Vienna.

NUMERICAL METHODS FOR UNCERTAINTY QUANTIFICATION

Credits: 4 **Semester:** 1 **Compulsory**: NO

Format :	**Lectures** **Examples** **Private study**	15h 5h 80h

Lecturers: A. Nouy

Contents:

This module introduces advanced numerical methods for uncertainty quantification in computational and predictive science. A particular attention is given to functional approaches for uncertainty quantification, namely spectral stochastic methods based on polynomial chaos type representations. Numerical methods are detailed for the quantification of input uncertainties and their propagation though physical models, in particular those involving stochastic partial differential equations. Some advanced topics are discussed such as adaptive approximation and enrichment, geometrical uncertainties, multiscale approaches, model reduction based on tensor product approximation for high-dimensional parametric and stochastic models.

Intended Learning Outcomes: to demonstrate

A knowledge and understanding of:	Challenges in uncertainty quantification in computational science; basics of functional approaches in probability and their use at the different steps uncertainty modeling, identification and numerical propagation through a computational model.
an ability to: (thinking skills)	Classify, formulate and analyze stochastic models; assess advantages, applicability and limitations of stochastic numerical methods and select a suitable method according to the desired probabilistic quantities and interest
an ability to: (practical skills)	Manipulate elementary statistical and probabilistic tools for uncertainty modeling (random variables and processes); implement basic spectral stochastic methods for the solution of stochastic PDEs.
an ability to: (key skills)	Study independently; use library resources; implement numerical methods for the solution of stochastic problems; effectively take notes and manage working time.

Assessment: 50% practical work 50% from end of Semester examination (open book).

Practical Work: Understand and explain a research paper on the topic. Exercises will be set, which will involve the implementation of numerical methods

Recommended texts: Lecture notes, *a selection of recent research papers on the topic.*

J. Jacod, P. Protter. *Probability essentials*. 2nd ed. Springer, 2004.

O.P. Le Maitre and O.M. Knio. *Spectral methods for uncertainty quantification*. Springer, 2010.

A. Nouy (2009). *Recent developments in spectral stochastic methods for the numerical solution of stochastic partial differential equations*. Arch Comput Methods Eng 16(3):251–285

Part II- Stuttgart
MSc modules distribution

3rd and 4th Semester University of Stuttgart

Elective Modules	**ECTS**
Computational Mechanics of Materials	6
Elements of Nonlinear Continuum Thermodynamics	6
Continuum Biomechanics	6
Geometrical Methods for Nonlinear Continuum Mechanics	6
Environmental Fluid Mechanics	6
Computational Material Science	3
Engineering Materials I- Metals, Concrete, Soils	3
Computational Methods of Shell Analysis	3
Foundation of Single and Multiphasic Materials	6
Micromechanics and Homogenization Methods	6
Advanced Computational Mechanics	6
Boundary Element Methods in Statics and Dynamics	6
Introduction to Continuum Mechanics of Multiphase Materials	6
Modeling of Hydrosystems	6
Parameter Identification Methods and Experimental Mechanics	6
Selected Topics in Plasticity and Viscoelasticity	6
Theoretical and Computer Oriented Materials Theory	6
Environmental Fluid Mechanics II	6
Engineering Materials II - Metals	3
Engineering Materials II - Concrete	3
Engineering Materials II - Soils	3
Implementation and Algorithms for Finite Elements	3
Transversal Modules	**ECTS**
Tendering, Contracting and Project Management	6
Project Planning and Financing	6

COMPUTATIONAL MECHANICS OF MATERIALS		
Credits: 6 **Term:** 2 **Compulsory**: No		
Format :	Lectures Examples Private study	32 h 20 h 128 h
Lecturer: C. MIEHE		
Contents:		
Introduction to discrete and continuous modeling of materials (microstructures, homogenization techniques and multi-scale approaches), fundamental theoretical concepts (basic rheology, classification of the phenomenological material response, elements of continuum thermodynamics), fundamental numerical concepts (discretization techniques for evolution systems, linearization techniques and iterative solution of nonlinear systems), linear and nonlinear elasticity, damage mechanics, viscoelasticity (linear and nonlinear models, stress update algorithms and consistent linearization), rate-independent plasticity (theoretical formulations, return mapping schemes, incremental variational formulations, consistent elastic-plastic tangent moduli), viscoplasticity (classical approaches and overstress models).		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	The students have a working knowledge of the behavior and modeling of elastic and inelastic materials in the one dimensional context. The students are further capable of performing numerical implementations of the classical material models of elasticity and inelasticity in the framework of the finite element method by using canonical algorithmic schemes.	
an ability to: (thinking skills)	Understand the different material responses and numerical implementation in the context of Finite Element Method in one dimension.	
an ability to: (practical skills)	Write their own material routines in connection with existing Finite Element codes for a variety of material responses using a programming language (MATLAB)	
an ability to: (key skills)	Study independently; synthesize diverse informations; use a personal computer for basic programming; work with commercial Finite Element Codes including the implementation of different material routines;	
Assessment: 3 homework assignments, 100% from end of Term examination (30% closed book).		
Recommended texts: Lecture Notes **Further readings:** Haupt, P. *Continuum Mechanics and Theory of Materials, Springer-Verlag*, 2002 Simo, J.C. & Hughes, T.J.R., *Computational Inelasticity,* Springer, 1998		

COMPUTATIONAL METHODS FOR SHELL ANALYSIS		
Credits: 3 **Term:** 3 **Compulsory**: No		
Format :	Lectures Examples Private study	21h 21h 138h
Lecturer: M. BISCHOFF		
Contents:		

The course covers design and analysis of shells, membrane and shell theory as well as mathematical and computational models for analysis of shells. The theoretical contents is supplemented and exemplified with applications of commercial finite element software.

- historical overview of shell theory
- geometrical basics and load carrying behavior
- shell models, prerequisites and assumptions
- membrane theory, basic equations and analytical solutions for shells of revolution
- computation of stress resultants and displacements
- bending theory, analytical solutions for cylindrical shells
- computational models for shells with arbitrary geometry, shear deformable (Reissenr/Mindlin) shell finite elements for
- non-linear analysis and stability.

Intended Learning outcomes: to demonstrate	
a knowledge and understanding of:	mechanical properties and load carrying behavior of plates and shells as well as the concepts of membrane theory and shell theory involving bending; modelling and simulation of shell problems with finite elements and the relationship of analysis, experiments and real behaviour of engineering structures; the peculiar behavior of shells in view of their imperfection sensitivity and their critical non-linear behavior (snap-through and buckling).
an ability to: (thinking skills)	adequately check and interpret computational results and handle the discrete quantities involved in shell finite elements; understand the most important shell models (Kirchhoff/Love, Reissner/Mindlin) and corresponding finite element formulations along with their respective advantages and drawbacks.
an ability to: (practical skills)	work self-dependently on a scientific level in the field of computational modeling of non-linear structural behavior; responsibly apply general purpose finite element packages to non-linear analysis of shells:
an ability to: (key skills)	critically survey simulation results and increased awareness about the general necessity to master classical theories when utilizing modern computational methods.

Assessment:

2 approved assignments (not graded), final exam (1h, graded, open book).

Recommended texts: lecture notes M. Bischoff, E. Ramm: Computational Methods for Shell Analysis, University of Stuttgart (yearly updated issues).

Further readings: M. Bischoff, K.-U. Bletzinger, W.A. Wall, E. Ramm: Models and Finite Elements for Thin-walled Structures. Encyclopedia of Computational Mechanics, Wiley (2004). C.R. Calladine: Theory of Shell Structures. Cambridge University Press (1983). H. Kraus: Thin Elastic Shells. Wiley (1967).

CONTINUUM BIOMECHANICS

Credits: 6 **Term:** 2 **Compulsory**: No

Format :	Lectures Examples Private study	28 h 18 h 120 h

Lecturer: W. Ehlers

Contents:

Biomechanical knowledge is the fundamental basis for the computation of processes inside (in vivo) and outside (in vitro) of living organisms. The lecture especially concerns soft biological tissues such as intervertebral discs. Hard biological tissues such as bones can be described as a special case of soft tissues. In the case of soft tissues, the solid deformation and pore-fluid flow of the complete system has to be handled. Herein, the tissue consists of a solid skeleton matrix (proteoglycans and collagen fibres) and an interstitial fluid mixture of pore water and a dissolved salt (e. g., NaCl). Hence, swelling and shrinking processes may occur, which have to be described. Moreover, electro-mechanical couplings have to be included in order to represent the active contractile behaviour of skeletal and cardiac muscles. In particular, the lecture offers the following content:

- Motivation and introduction
- Biological Tissues as Porous Media
  1. The intervertebral disc as an exemplary soft biological tissue
  2. Basic swelling mechanisms (van't Hoff osmosis)
  3. Basic growth modelling
- Passive biological materials
  1. Basic concepts and fundamentals of hyperelastic materials
  2. Nonlinear material modelling (isotropy, transverse isotropy, general fibre reinforcements)
  3. Residual stresses
  4. Material parameter fitting and sensitivity analysis
- Active biological materials
  1. Electro-mechanical material behaviour of skeletal and cardiac muscles
  2. Basics of electro-physiology (Hill relation, crossbridge dynamics)
  3. Bidomain equation
  4. Constitutive laws for electro-mechanical biological tissue
  5. Coupling and homogenisation techniques

Intended Learning outcomes: to demonstrate

a knowledge and understanding of:	fundamentals of the continuum mechanical modelling of living organisms with special attention to soft biological tissues; multiphysical effects in multiphasic materials on different length and time scales.
an ability to: (thinking skills)	understand the application of continuum-mechanical methods to describe biological tissues and develop a feeling for the complexity of living systems.
an ability to: (practical skills)	develop continuum mechanical models that capture the active and passive behaviour of biological tissues resulting from electro-chemical and electro-mechanical couplings.
an ability to: (key skills)	study independently; use library resources; effectively take notes and manage working time.

Assessment: 3 homework assignments, 100% from end of Term examination (100% open book).

Recommended texts: Lecture notes
Fung, Y., Mechanical Properties of Living Tissues, Springer, Berlin 1984.
Mow, V. C., Hayes, W. C. (eds.), Basic Orthopaedic Biomechanics, 2nd Edition, Lippincott-Raven, Philadelphia 1997.
Karajan, N., An extended biphasic description of the inhomogeneous and anisotropic intervertebral disc, Dissertation, Report No. II-19, Institut für Mechanik (Bauwesen), Universität Stuttgart 2009.

ELEMENTS OF NONLINEAR CONTINUUM MECHANICS AND CONTINUUM THERMODYNAMICS		
Credits: 6 **Term:** 2 **Compulsory**: No		
Format :	Lectures Examples Private study	28 h 18 h 120 h
Lecturer: W. Ehlers		

Contents:

Fundamental knowledge of nonlinear continuum thermodynamics is a crucial prerequisite for the description of large deformations of arbitrary materials with nonlinear constitutive laws. The lecture provides a systematic representation of nonlinear continuum mechanics and the basics of thermodynamics (energy balance, entropy inequality). Proceeding from the fundamental principles of constitutive theory and the 2nd law of thermodynamics, the procedure for the derivation of thermodynamic consistent and admissible material models is described. All methods are exemplarily applied for the description of a nonlinear deformable, thermoelastic solid. Moreover, some aspects of the numerical treatment of nonlinear processes in space and time are discussed. In particular, the lecture comprises the following topics:.

- Continuum mechanical basics
- Nonlinear deformation and strain measures of a solid body
- Nonlinear stress tensors
- Master balance principle and specific balances for mass, momentum and moment of momentum
- Thermodynamic principles
  1. Balance of energy (first law of thermodynamics)
  2. Entropy inequality (second law of thermodynamics)
  3. Elements of classical thermodynamics (internal energy and caloric state variables, thermodynamic potentials, Legendre transformations)
- Introduction to thermodynamic materials theory
  1. Admissible constitutive equations and process variables
  2. Basic thermodynamic modelling principles (material symmetry, observer invariance)
  3. Nonlinear elasticity laws (Neo-Hooke, Mooney-Rivlin, Simo-Pister, Flory, Ogden)
  4. Application: 3-d thermoelasticity at finite strains with evaluation of the entropy principle
- Numerical aspects
  1. Time integration of coupled problems and weak form of the boundary value problem
  2. Consistent linearisation of the field equations
  3. Stability criteria

Intended Learning outcomes: to demonstrate	
a knowledge and understanding of:	fundamentals of nonlinear continuum mechanics including the nonlinear motion of a body, thermodynamical modelling principles for arbitrary materials, application to finite elasticity/ thermoelasticity as well as numerical implementation aspects.
an ability to: (thinking skills)	understand the physical and mechanical coherences in the modelling of engineering problems.
an ability to: (practical skills)	develop an admissible continuum mechanical model (primary variables, balance equations, constitutive equations) and its numerical implementation to describe the behaviour of non-linear materials.
an ability to: (key skills)	study independently; use library resources; effectively take notes and manage working time.

Assessment: 3 homework assignments, 100% from end of Term examination (100% open book).

Recommended texts: Lecture notes

Haupt, P., Continuum Mechanics and Theory of Materials, Springer-Verlag, Berlin 2000
Holzapfel, G. H., Nonlinear Solid Mechanics, John-Wiley & Sons, Chichester 2000
Ogden, R. W., Non-linear Elastic Deformations. Dover Publications, Mineola (NY) 1997

ENGINEERING MATERIALS I: METALS, CONCRETE, SOILS

Credits: 3 **Term:** 1 **Compulsory**: No

Format :	Lectures Examples Private study	21 h 0 h 69 h

Lecturer:

Prof. Dr. rer. nat. Siegfried Schmauder

Prof. Dr.-Ing. Jan Hoffmann

Prof. Dr.-Ing. Christian Moormann

Contents:

Metals:

The aim of this module is to provide the student with a working knowledge for the theoretical background of the crystal structure and the deformation processes in metals on the atomistic level. The different hardening procedures, and their metallographic mechanisms are understood. The students know the main influence factors on the mechanical behavior of metals. Examples and tasks will be given for each of the topics:

- Fundamentals of dislocation theory
- Plastic deformation of metals
- Possibilities of increasing the strength
- Influence on the material behaviour

Concrete:

The students get a deep understanding of the behaviour of concrete, a very heterogeneous and rather brittle material, under compression and tension loading. They understand the influence of test conditions, light weight aggregates and fibres on concrete properties.

Soils:

The aim of this section is to provide an understanding of

- Stresses in Soils
- Stiffness of Soils
- Strength of soils

Intended Learning outcomes: to demonstrate

A knowledge and understanding of:	Theoretical background of the behaviour, the modelling and the designing of the different engineering materials. A knowledge of the influences and the material parameters to describe the materials behaviour under loading and deformation.
an ability to: (thinking skills)	Understand the different material responses and influences and the possibility to transfer these parameters into programming parameters.
an ability to: (practical skills)	Calculating and describing the material with formulas depending on different influence parameters.
an ability to: (key skills)	Study independently; synthesize diverse information's; transfer knowledge from one material to other comparable materials

Assessment: homework assignments, Metals, 33%, written, 40 min, Concrete, 33%, written, 40 min, Soils, 33%, written, 40 min

Recommended texts: lecture specific manuscript and additional information in the internet
Further reading, Compendium and lecture presentations.

Further readings:

- R.E. Smallman, R.J. Bishop: Metals and Materials - Science, Processes, applications;; Butterworth-Heinemann Ltd. Oxford, 1995
- Illston, J. M.: Construction Materials: Their Nature and Behaviour, SPON, 2001
- Neville A. M.: Properties of Concrete, 4th Edition, available from several publishers
- Soil Mechanics“, an elementary textbook that is available in the internet under http://geo.verruijt.net/software.html

ENVIRONMENTAL FLUID MECHANICS I

Credits: 6 **Term:** 1 **Compulsory**: No

Format :	Lectures Exercises Private study	36 h 24 h 120 h

Lecturer: R: HELMIG, H. CLASS

Contents:

The lecture deals with flow in natural hydrosystems with particular emphasis on groundwater / seepage flow and on flow in surface water / open channels. Groundwater hydraulics includes flow in confined, semi-confined and unconfined groundwater aquifers, wells, pumping tests and other hydraulic investigation methods for exploring groundwater aquifers. In addition, questions concerning regional groundwater management (e.g. recharge, unsaturated zone, saltwater intrusion) are discussed. Using the example of groundwater flow, fundamentals of CFD (Computational Fluid Dynamics) are explained, particularly the numerical discretization techniques finite volume and finite difference. The hydraulics of surface water deals with shallow water equations / Saint Venant equations, instationary channel flow, turbulence und layered systems. Calculation methods such as the methods of characteristics are explained.

The contents are:

- Potential flow and groundwater flow
- Computational Fluid Dynamics
- Shallow water equations for surface water
- Method of Characteristics
- Examples from civil and environmental engineering

Intended Learning outcomes: to demonstrate

A knowledge and understanding of:	Students have fundamental knowledge of flow in various natural hydrosystems and its application in civil and environmental engineering.
an ability to: (thinking skills)	Having an overview of fundamental methods and equations to describe the different hydrosystems
an ability to: (practical skills)	Being able to solve basic engineering problems related to hydrosystems, finding own solution strategies
an ability to: (key skills)	Filtering information in a vast field of engineering, synthesizing common methods from different applications

Assessment: Written examination (120 min.)

Recommended texts:

Lecture notes: Hydromechanics, Helmig and Class

Lecture notes: Ausbreitungs- und Transportvorgänge in Strömungen, Cirpka

Further readings:

White, F.M.: Fluid Mechanics, WCB/McGraw-Hill, New York, 1999

Freeze, R.A. and Cherry J.A.: Groundwater, Prentice Hall, 1979

GEOMETRICAL METHODS FOR NONLINEAR CONTINUUM MECHANICS AND THERMODYNAMICS

Credits: 6 **Term:** 2 **Compulsory**: No

Format :	Lectures Examples Private study	32 h 20 h 128 h

Lecturer: C. MIEHE

Contents:

The knowledge of continuum mechanics and continuum thermodynamics is the fundamental requirement for the theoretical and algorithmic understanding of geometrically and physically nonlinear deformation, failure and transport processes in solids consisting of metallic, polymer or geological materials. This course offers a presentation of fundamental concepts of continuum mechanics and constitutive theory at finite elastic and inelastic strains. The chosen formulation accentuates geometrical aspects based on the modern terminology of differential geometry, which also includes the description of multi-field theories with thermo- and electromechanical coupling. Algorithmic aspects of the computer implementation of nonlinear continuum mechanics models are covered in parallel to the theoretical description. Contents:

- Tensor algebra and -analysis on manifold
- Differential geometry of finite deformations
- Balance principles of nonlinear continuum thermodynamics
- Phenomenological material theory at finite strains
- Uniqueness of boundary value problems and stability theory

Intended Learning outcomes: to demonstrate

A knowledge and understanding of:	The students understand fundamental concepts of nonlinear continuum thermodynamics as the basis for the phenomenological, macroscopic description of engineering processes for solids and fluids at finite deformations and complex material behavior, which also takes into account stability problems and material failure. Through the rigorous, deductive presentation of the subject in the course the students can directly connect to more advanced applications of this important field of research based on the terminology of modern differential geometry.
an ability to: (thinking skills)	The students understand fundamental concepts of nonlinear continuum thermodynamics.
an ability to: (practical skills)	Write their own material routines in connection with existing Finite Element codes for a variety of material responses using a programming language (MATLAB)
an ability to: (key skills)	Study independently; synthesize diverse informations; use a personal computer for basic programming; work with commercial Finite Element Codes including the implementation of different material routines;

Assessment: Homework assignments, 100% from end of Term examination

Recommended texts: Lecture Notes

Further readings: Marsden, J. E. & Hughes, T.J.R. *Mathematical Foundations of Elasticity, Prentice-Hall, Inc., Englewood Cliffs, New Jersey* 1983

<table>
<tr><th colspan="3">ADVANCED COMPUTATIONAL MECHANICS OF STRUCTURES</th></tr>
<tr><td colspan="3">Credits: 6 Term: 2 Compulsory: No</td></tr>
<tr><td>Format :</td><td>Lectures
Examples
Private study</td><td>21h
21h
138h</td></tr>
<tr><td colspan="3">Lecturer: M. BISCHOFF</td></tr>
<tr><td colspan="3">Contents:</td></tr>
<tr><td colspan="3">The course covers the theory of non-linear structural mechanics and corresponding discretization methods and algorithms with a focus on the finite element methods.
• Basic principles, phenomena and concepts of structural mechanics,
• non-linear strain measures and stress measures,
• large deformations, stability problems,
• methods and algorithms of non-linear structural mechanics,
• iteration methods and path following techniques as well as
• stability analysis and buckling problems.</td></tr>
<tr><td colspan="3">Intended Learning outcomes: to demonstrate</td></tr>
<tr><td>a knowledge and understanding of:</td><td colspan="2">computational methods for the non-linear analysis of structures with an emphasis on the finite element method..</td></tr>
<tr><td>an ability to:
(thinking skills)</td><td colspan="2">critically review computational results and their relationship to experiments in the field of non-linear structural mechanics, decide about a feasible choice of computational models and software to solve a specific problem.</td></tr>
<tr><td>an ability to:
(practical skills)</td><td colspan="2">work self-dependently on a scientific level in the field of computational modeling of non-linear structural behavior.</td></tr>
<tr><td>an ability to:
(key skills)</td><td colspan="2">study with an own responsibility, consult additional literature, gain insight into aims and methods of scientific work in an international environment.</td></tr>
<tr><td colspan="3">Assessment: .
3 approved assignments (not graded), final exam (2h, graded, open book).</td></tr>
<tr><td colspan="3">Recommended texts: lecture notes M. Bischoff, E. Ramm: Advanced Computational Mechanics of Structures, Institute of Structural Mechanics, University of Stuttgart (yearly updated issues).
Further readings:
D.Talaslidis, G. Wempner: Mechanics of Solids and Shells, Theory and Approximations. CRC Press, 2003.
T. Belytschko, W.K. Lin, B. Moran: Nonlinear Finite Elements for Continua and Structures. Wiley, 2000..</td></tr>
</table>

BOUNDARY ELEMENT METHODS IN STATICS AND DYNAMICS		
Credits: 6 **Term:** 2 **Compulsory**: No		
Format :	Lectures Examples Private study	30h 10h 125h
Lecturer: L. GAUL		
Contents:		
The module covers the numerical solution of boundary value problems by boundary element methods (BEM). Boundary integral equations are derived from weighted residual techniques with fundamental solutions as weighting functions. The numerical implementation of BEM covers the discretization of geometry and boundary data, numerical integration of boundary integrals and field data evaluation. Application to problems in potential theory (heat conduction), acoustics and elastomechanics including structure borne sound propagation are presented. An outlook on advanced topics like fast Multipole BEM, hybrid BEM, Dual Reciprocity BEM and BEM-FEM mortar coupling is given.		

Intended Learning outcomes: to demonstrate	
a knowledge and understanding of:	the fundamentals of boundary element methods and their numerical implementation; advantages, applicability and comparison to FEM.
an ability to: (thinking skills)	understand and formulate basic BEM procedures and solve illustrative problems.
an ability to: (practical skills)	implement basic techniques such as numerical integration and to develop a complete simple BEM-code in a step-by-step guided homework project with the programming language Matlab; understand commercial BE-programs.
an ability to: (key skills)	study independently and in team; use a personal computer for solving BEM problems and do basic programming; project work; effectively take notes and manage working time.
Assessment: 100% from end of Term examination (closed-book). 50% of the homework problems and projects are mandatory for the admission to the examination.	
Recommended texts: Lecture notes on the homepage of the online-module: www.bem.uni-stuttgart.de (Authors: Gaul, L., Fischer, M.) Gaul, L., Kögl, M., Wagner, M., *Boundary Element Methods for Engineers and Scientists*, Springer, 2003 **Further readings:** Gaul, L., Fiedler, C., *Methode der Randelemente in Statik und Dynamik*, Vieweg, 1997	

ENGINEERING MATERIALS II - CONCRETE		
Credits: 3 **Term:** 2 **Compulsory**: No		
Format :	Lectures Examples Private study	21 h 6 h 64 h
Lecturer: J. OŽBOLT		

Contents:

The development of computational models for detailed 3D finite element analysis of structures made of quasi-brittle materials is treated. Strong emphasis is placed on the application of these models to concrete and reinforced concrete structures. The topics of regularization techniques and adaptive remeshing are also discussed.

- Quasibrittle materials and motivation for non-linear analysis
- Review of concrete behaviour in tension and compression
- Modelling of concrete and basic thermodynamic principles
- Fracture mechanics (LEFM, NLFM and size effect)
- Plasticity based constitutive laws for concrete
- Damage based constitutive laws
- "The Smeared Crack Models"
- Microplane theory
- Objective modelling (regularization) and new developments
- Coupled problems (chemo-thermo-hygro-mechanical models)

Intended Learning outcomes: to demonstrate	
a knowledge and understanding of:	The variety of methods currently used to numerically model concrete and reinforced concrete; the theoretical background for these methods; computational issues related to the detailed modelling of concrete and reinforced concrete
an ability to: (thinking skills)	Express complex quasi-brittle material behaviour in a computational environment; understand the basic principles of the presented modelling frameworks
an ability to: (practical skills)	Select an appropriate framework for a given application; identify and know how to avoid common pitfalls in the numerical modelling of quasibrittle materials
an ability to: (key skills)	Study independently; synthesize diverse information; use a personal computer for basic programming; effectively take notes and manage working time

Assessment: Optional biweekly homework assignments, 100% from end of Term examination.

Recommended texts:

Jirasek, M. & Bažant, Z. P.: *Inelastic Analysis of Structures*, J. Wiley and Sons, 2002
Karihaloo, B. L.: *Fracture Mechanics & Structural Concrete*, Longman Scientific & Technical, 1995

Further readings:

Mazars, J. & Pijaudier-Cabot, G.: Continuum Damage Theory – Application to Concrete; Journal of Engineering Mechanics; Vol. 115; No. 2; 1989; 345-365
Ožbolt, J., Li, Y. & Kožar, I.: Microplane Model for Concrete with Relaxed Kinematic Constraint; International Journal of Solids and Structures, 38, 2001, 2683-2711
Rots, J. G.: Crack Models for Concrete: Discrete or Smeared? Fixed, Multi-Directional or Rotating?; Heron; Vol. 34, No. 1; 1989; 56 pgs.
Ožbolt, J., Sharma, A. and Reinhardt, H.W.: Dynamic fracture of concrete – compact tension specimen; International Journal of Solids and Structures, 48, 2011, 1534–1543.

ENGINEERING MATERIALS II – METALS		
Credits: 3 **Term:** 2 **Compulsory**: No		
Format :	Lectures Examples Private study	14h 14h 69h
Lecturer: Siegfried Schmauder		
Contents:		

The aim of this module is to provide the student with a working knowledge for the modeling of metallic materials typically encountered in engineering design and analysis. This module focuses on understanding and predicting the mechanical behaviour of metals including static, dynamic and creep loading for a variety of problems in science and engineering. Emphasis will be placed on plasticity-based approaches for numerical analyses, strength calculations for static loading conditions as well as for cyclic loading, the mechanical behavior of materials including creep, the influences of notches and on the impact of damage and fracture in metals. Examples and tasks will be given for each of the topics:

- Mechanical Behavior of Metals
- Notches, Creep
- Damage and Fracture

Intended Learning outcomes: to demonstrate	
a knowledge and understanding of:	the fundamentals of the mechanical behaviour of metallic materials including deformation and fracture; models to solve problems in the field of simulating material behaviour.
an ability to: (thinking skills)	understand and formulate basic tasks of the mechanical behavior of metals; solve illustrative problems and identify proper methods for their solutions.
an ability to: (practical skills)	understand practical implications of analytical means, methods and solutions; logically formulate problems and evaluate practically relevant experimental and numerical results for metals.
an ability to: (key skills)	study independently; use library resources; apply analytical and numerical tools as well to perform strength calculations; effectively take notes and manage working time.

Assessment: No continuous assessment assignments; end of term examination (100%).

Practical Work: Exercises will be set, which will involve coding of the presented methods.

Recommended texts: Lecture notes
Smallman, R.E., Bishop, R.J., Metals and Materials, Science, Processes, Applications, Butterworth-Heinemann Ltd., Oxford, 1995

Further readings:
Raabe, D., Computational Materials Science, Wiley-VHC, Weinheim, 1998

ENGINEERING MATERIALS II - SOILS		
Credits: 2 **Term:** 2 **Compulsory**: No		
Format :	Lectures Examples Private study	14h 4h 40h
Lecturer: C. Moormann & P.A. Vermeer		

Contents:

This module focuses on applications of rate independent elastoplastic constitutive models to simulate material responses of cohesive-frictional soils. The responses such as stress-strain relation and contraction-dilation behaviour before perfectly plastic state (Mohr-Coulomb failure boundary), are modelled based on 2 hardening laws: shear or frictional hardening and density or cap hardening. In the models, the use of non-associated flow rule originated from the concept of stress dilatancy is shown to be essential. An overview about some special topics such as viscous effects in soft soils and small strain stiffness is given also in this module.

- Density Hardening Model for loose Soils.
  1. Undrained soil testing with special reference to NC-clays and sands.
  2. Formulation of elastoplastic density hardening model
  3. Evaluation of the model.
- Friction Hardening Model for Dense Soils.
  1. Stress-strain curves from triaxial tests.
  2. Hyperbolic approximation.
  3. Shear-strain contours.
  4. Flow rule and plastic potential.
  5. Final elastoplastic model.
- Double Hardening Model.

  Combination of friction and density hardening models.

Intended Learning outcomes: to demonstrate

a knowledge and understanding of:	Advantages and limitations of each soil models, as well as the selection of suitable input parameters from laboratory tests.
an ability to: (thinking skills)	understand the soil mechanical behaviour (clays and sands) and identify the proper constitutive model for the corresponding soil.
an ability to: (practical skills)	understand practical implications of soils behaviour and simulate it using a suitable advanced constitutive models.
an ability to: (key skills)	study independently; use library resources effectively take notes and manage working time.

Assessment: 100% from end of Term examination (closed-book).

Practical Work: Exercises will be set, which will involve deriving some constitutive equations and soil behaviour prediction under specific stress paths.

Recommended texts: Lecture notes

Biarez, J. & Hicher, P., *Elementary Mechanics of Soil Behaviour*, Balkema-Publishers, 1994

Wood, D.M., *Soil Behaviour and Critical State Soil Mechanics*, Cambridge University Press,1990

Further readings:

Brinkgreve, R & Vermeer, P. A. *Plaxis Version 7*, Balkema-Publishers, 1998

ENVIRONMENTAL FLUID MECHANICS II		
Credits: 6 **Term:** 2 **Compulsory**: No		
Format :	Lectures Exercises Private study	33 h 22 h 125 h
Lecturer: W. NOWAK, R. HELMIG		
Contents:		
The lecture deals with the heat and mass budget of natural and technical systems. This includes transport processes in lakes, rivers and groundwater, heat and mass transfer processes between compartments as well as between various phases (sorption, dissolution), conversion of matter in aquatic systems and the quantitative description of these processes. In addition to classical single fluid phase systems, multiphase flow and transport processes in porous media will be considered. On the basis of a comparison of single- and multiphase flow systems, the various model concepts will be discussed and assessed. In the accompanying exercises, example problems present applications, extend the lecture material and help to prepare for the exam. Computer exercises improve the grasp of the problems and give insight into the practical application of what has been learned.		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	Students have the necessary grasp of hydrodynamic, physical and chemical processes and systems to be able to answer environmentally relevant questions concerning water and air quality in natural and technical systems.	
an ability to: (thinking skills)	Comprehension of very detailed knowledge of complex interacting physical processes.	
an ability to: (practical skills)	Computer application, independend learning, using scientific literature	
an ability to: (key skills)	Study independently, work with available software tools.	
Assessment: Written examination (120 min.)		
Recommended texts: Lecture notes: Fluidmechanics II, Helmig **Further readings:** Helmig, R.: Multiphase Flow and Transport Processes in the Subsurface. Springer, 1997		

FOUNDATIONS OF SINGLE- AND MULTIPHASIC MATERIALS		
Credits: 6 **Term:** 2 **Compulsory**: No		
Format :	Lectures Examples Private study	28 h 18 h 120 h
Lecturer: W. Ehlers		
Contents:		

The major objective of this elective module is to discuss the thermodynamical principles of continuum mechanics in order to provide an admissible constitutive framework for the theory of materials. Therefore, the content is split into three main parts: Thermodynamics, introduction to materials theory and fluid-saturated porous solid materials.

Thermodynamics

- Thermodynamic balance laws
  - Balance of energy (first law of thermodynamics)
  - Entropy inequality (second law of thermodynamics)
  - Thermodynamical potentials
  - Application: 3-d thermoelasticity at finite strains

Introduction to materials theory

- Geometrically linear thermoelasticity
  1. Linearisation of the finite problem
  2. Inversion of the linear law of thermoelasticity
  3. Determination of material parameters
- Geometrically linear viscoelasticity
  1. Motivation and basic model rheology
  2. The standard model of viscoelasticity
  3. Clausius-Planck inequality and internal dissipation
  4. The 3-d viscoelastic solid
- Geometrically linear elastoplasticity
  1. Motivation and basic model rheology
  2. Metal plasticity
  3. Generalised geomaterials plasticity

Fluid-Saturated porous solid materials

1. Basic concepts
2. Mechanical balance relations
3. Constitutive equations
4. Darcy's filter law

Intended Learning outcomes: to demonstrate

a knowledge and understanding of:	fundamentals of continuum thermodynamics with application to thermoelasticity, viscoelasticity and elastoplasticity; fundamentals of the Theory of Porous Media.
an ability to: (thinking skills)	understand the physical and mechanical coherences in the modelling of engineering problems.
an ability to: (practical skills)	develop an admissible continuum mechanical model (primary variables, balance equations, constitutive equations) describing the behaviour of materials.
an ability to: (key skills)	study independently; use library resources; effectively take notes and manage working time.

Assessment: 3 homework assignments, 100% from end of Term examination (100% open book).

Recommended texts: Lecture notes
Haupt, P., Continuum Mechanics and Theory of Materials, Springer-Verlag, Berlin 2000
Holzapfel, G. H., Nonlinear Solid Mechanics, John-Wiley & Sons, Chichester 2000

IMPLEMENTATION AND ALGORITHMS FOR FINITE ELEMENTS
Credits: 2 **Term:** 3 **Compulsory**: No

Format :	Lectures Examples Private study	10.5h 10.5h 69h

Lecturer: M. VON SCHEVEN

Contents:

- principal structure of a finite element code
- pre- and post-processing, software engineering in the context of finite element programs
- integration of element stiffness matrices and load vectors, implementation of boundary conditions
- assembly of stiffness matrices
- solution of linear systems of equations
- storage formats for sparse matrices
- linearizationand iterative solution of non-linear equations
- eigen value analysis.

Intended Learning outcomes: to demonstrate

a knowledge and understanding of:	numerical methods and algorithms for implementation of the finite element method as well as the most important methods of numerical mathematics
an ability to: (thinking skills)	understand the individual components of complex finite element packages and the structure and logic of a scientific programming language.
an ability to: (practical skills)	produce their own finite element code and implement methods of numerical mathematics by using a scientific programming language.
an ability to: (key skills)	self-dependent study of numerical methods on a scientific level and critical survey of such methods as available in commercial software.

Assessment: .

2 approved assignments (not graded), final exam (1h, graded, open book).

Recommended texts: lecture notes M. von Scheven: Implementation and Algorithms for Finite Elements, Institute of Structural Mechanics, University of Stuttgart (yearly updated issues).

Further readings:

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INTRODUCTION TO THE CONTINUUM MECHANICS OF MULTIHASE MATERIALS		
Credits: 6 **Term:** 2 **Compulsory**: No		
Format :	Lectures Examples Private study	28 h 18 h 120 h
Lecturer: W. Ehlers		
Contents:		

Porous solids with a fluid pore content as well as real mixtures of liquids and gases belong both to the class of multi-phase materials. With a continuum theory for multiphasic media, the movement or flow of fluids in deformable porous solids can be described for arbitrary deformation processes and arbitrary material properties of the solid matrix. Moreover, it is possible to consider phase transitions and electro-chemical reactions within such a theory.

In this regard, the major objective of this module is to provide a theoretical tool that can be used to mathematically describe and numerically analyse a manifold of distinct materials, ranging from geomaterials over polymer and metal foams to biological tissues. For the numerical application, a system of strongly coupled partial differential equations has to be solved. In particular, the course embraces the following topics:

- Continuum-mechanical basics for the description of single- and multiphasic materials:
  1. State of motion
  2. Deformation and strain measures
  3. Stress states
- Balance relations for multiphase materials:
  1. Master balance principle
  2. Special balances for mass, momentum, moment of momentum, energy and entropy
- Caloric state variables and energy potentials
- Fundamentals of materials theory for multiphasic media
  1. Thermodynamics and constitutive equations
  2. The fluid-saturated, materially incompressible deformable porous solid
  3. Elastic material properties of the solid skeleton
  4. Plastic behaviour of the solid skeleton (optional)

Intended Learning outcomes: to demonstrate	
a knowledge and understanding of:	fundamentals of the Theory of Porous Media including the principles of thermodynamical modelling and application to multiphasic materials with a viscous pore fluid and an elasto-plastic solid skeleton.
an ability to: (thinking skills)	understand the physical and mechanical coherences in the modelling of engineering problems.
an ability to: (practical skills)	develop an admissible continuum mechanical model (primary variables, balance equations, constitutive equations) describing the behaviour of coupled multiphasic materials.
an ability to: (key skills)	study independently; use library resources; effectively take notes and manage working time.

Assessment: 3 homework assignments, 100% from end of Term examination (100% open book).

Recommended texts: Lecture notes

Ehlers, W., Foundations of multiphasic and porous materials. In Ehlers, W.; Bluhm, J. (eds.): Porous Media: Theory, Experiments and Numerical Applications, pp. 3-86, Springer, Berlin 2002.
Truesdell, C.; Noll, W., The Non-linear Field Theories of Mechanics. In Flügge, S. (ed.): Handbuch der Physik, Band III/3, Springer, Berlin 1965.
Holzapfel, G. H., Nonlinear Solid Mechanics, John-Wiley & Sons, Chichester 2000

MICROMECHANICS OF MATERIALS AND HOMOGENIZATION METHODS

Credits: 6 **Term:** 2 **Compulsory**: No

Format :		
	Lectures	28 h
	Examples	18 h
	Private study	120 h

Lecturer: C. MIEHE

Contents:

The module covers basic concepts of the theoretical formulation and numerical implementation of elastic and inelastic material response at small strains. It introduces generic classes of material models for elasticity, viscoelasticity, plasticity, viscoplasticity and damage mechanics based on the exploitation of fundamental axioms of continuum-thermodynamics. Parallel to the theoretical set up, details of appropriate numerical solution algorithms for finite element implementations are taught in an integrated manner related to the specific material models. A focus is put on a differentiation between purely phenomenological and micromechanically-based constitutive models. This includes discussions of microstructures of elastically and plastically deforming metallic crystals, polymers and granular materials. These scenarios are put into the general context of a multiscale picture of materials. To this end the module introduces foundations of homogenization methods and micro-to-macro transitions.

- Foundations of continuum thermodynamics at small strains: kinematics, balance principles, dissipation postulates.
- Theory and numerics of generic classes of material response: elasticity, viscoelasticity, plasticity, viscoplasticity and damage mechanics.
- Micromechanically-based constitutive models for metallic crystals and polymers.
- Multiscale modelling of materials and computational homogenization methods.

Intended Learning outcomes: to demonstrate

A knowledge and understanding of:	Theoretical and computational foundations of constitutive modelling for basic phenomenological classes of materials, micromechanically-based models and multiscale characteristics of materials
an ability to: (thinking skills)	Understand the different material responses and numerical implementation in the context of Finite Element Method on different length scales.
an ability to: (practical skills)	Write their own material routines in connection with existing Finite Element codes for a variety of material responses using a programming language (C or Fortran 77)
an ability to: (key skills)	Study independently; synthesize diverse informations; use a personal computer for basic programming; work with commercial Finite Element Codes including the implementation of new material routines;

Assessment: 3 homework assignments, 100% from end of Term examination (30% closed book).

Recommended texts: Maugin, G.A., *The Thermomechanics of Plasticity and Fracture,* Cambridge, 1992
Lemaitre, J.& Chaboche, J.-L., *Mechanics of Solid Materials,* Cambridge, 1990
Simo, J.C. & Hughes, T.J.R., *Computational Inelasticity,* Springer, 1998

Further readings: C. Miehe [2002], "Strain-Driven Homogenization of Inelastic Microstructures and Composites Based on an Incremental Variational Formulation", *International Journal for Numerical Methods in Engineering* 55 Issue 11 (2002), pp. 1285-1322.
C. Miehe & A. Koch [2002], "Computational Micro-to-Macro Transitions of Discretized Micro-Structures Undergoing Small-Strain Deformations", *Archive of Applied Mechanics* 72 (2002), pp.300-317.

MODELING OF HYDROSYSTEMS		
Credits: 6 **Term:** 2 **Compulsory**: No		
Format :	Lectures Exercises Private study	33 h 22 h 125 h
Lecturer: R. HELMIG, B. FLEMISCH, H. CLASS		

Contents:

Discretization methods:
- Knowledge of common methods (finite differences, finite elements, finite volume) and the differences between them
- Advantages and disadvantages of the methods, thus also their applicability
- Derivation of various methods
- Use and choice of the correct boundary conditions for the methods

Time discretization:
- Knowledge of various possibilities
- Assessment of stability, computational effort, precision

5. Courant number, CFL criterion

Transport equation:

6. Various discretization possibilities
7. Physical background
8. Stability criteria of the methods (Peclet number)

Choice of a grid.
Exemplary discussion of discretization techniques on the basis of the stationary groundwater equation.
Time discretization on the basis of the instationary groundwater equation:
- explicit and implicit methods

Discretization of the transport equation:
- Central difference methods, upwinding

Introduction to stability analysis, convergence.
Application of the finite element method to the stationary groundwater equation.
Setting-up of a simulation program for modeling groundwater flow:
- Program requirements
- Programming individual routines

Fundamentals of programming in C:
- Control structures, functions, arrays, debugging

Visualization of the simulation results

Intended Learning outcomes: to demonstrate

A knowledge and understanding of:	Students can select suitable numerical methods for solving problems from fluid mechanics and have basic knowledge of implementing a numerical model in C.
an ability to: (thinking skills)	Understand that different numerical methods can have limitations, advantages, and disadvantages, which all have to be considered when choosing a method for a practical problem.
an ability to: (practical skills)	Programming skills (C language), practical use of simulation tools, graphics software, debuggers, etc.
an ability to: (key skills)	Concentrating on a continuous work, learning that multiple solutions for a problem exist and judging the best one requires profound knowledge

Assessment: Written examination (120 min.)

Recommended texts:
Lecture notes: Modeling of Hydrosystems, Helmig
Further readings:
Helmig, R.: Multiphase Flow and Transport Processes in the Subsurface, Springer Verlag, 1997

PARAMETER IDENTIFICATION METHODS AND EXPERIMENTAL MECHANICS		
Credits: 6 **Term:** 2 **Compulsory**: No		
Format :	Lectures Examples Private study	32 h 20 h 128 h
Lecturer: C. MIEHE		

Contents:

The model construction for phenomenological material response involves two main steps. First, it requires the formulation of a mathematical model to capture the physical effects. Then, the parameters of the underlying material model must be determined from experiments. The determination of material parameters therefore leads to an inverse problem, in which the unknown parameters must be fit to the experiments in an optimal sense. A classical approach to the identification of material parameters is the error minimization between model simulation and experimental data. This procedure leads to a highly-nonlinear optimization problem, in which the material parameters are the independent variables, known as parameter identification. The lecture offers an introduction to the basic concepts of experimental mechanics and parameter identification as well as nonlinear optimization with applications to selected model problems. Contents:

- Basic concepts of experimental material mechanics
- The inverse problem of parameter identification
- Nonlinear optimization methods and sensitivity analysis
- Gradient-based methods, evolution strategies, neural networks
- Finite element implementation of inhomogeneous problems
- Application to representative model problems

Intended Learning outcomes: to demonstrate

A knowledge and understanding of:	The students understand methods for the determination of optimal parameters in complex material models, which play a central role in the construction of predictive computer-oriented simulation methods, and require an all-encompassing consideration of theoretical model formulation, numerical implementation, simulation and comparison with experiments. They know the concepts of parameter identification and the solution of inverse problems in mechanics on the basis of nonlinear optimization methods.
an ability to: (thinking skills)	The students understand fundamental concepts in nonlinear optimization methods with a focus on parameter identification in material models.
an ability to: (practical skills)	Write their own material routines in connection with existing codes for a variety of optimization problems using a programming language (MATLAB)
an ability to: (key skills)	Study independently; synthesize diverse informations; use a personal computer for basic programming; Codes including the implementation of optimization algorithms;

Assessment: Homework assignments, 100% from end of Term examination

Recommended texts: Lecture Notes

SELECTED TOPICS IN THE THEORIES OF PLASTICITY AND VISCOELASTICITY		
Credits: 6 **Term:** 2 **Compulsory**: No		
Format :	Lectures Examples Private study	32 h 20 h 128 h
Lecturer: C. MIEHE & W. EHLERS		
Contents:		
• The ultimate goal of the lecture to foster the understanding of general inelastic material behavior with regard to the theoretical modeling and the numerical treatment based on selected model problems. As an example, the selected material models under consideration may cover (i) micromechanically motivated approaches to inelastic material response such as crystal plasticity or (ii) purely phenomenological formulations of an inelastic material response such as viscoelasticity. Contents: • • Introduction to inelastic material behavior • Micromechanical structure of solids • Kinematics of inelastic deformations at finite strains • Foundations of continuum-based material modeling for selected problems, e.g. finite crystal plasticity and viscoelasticity • Integration algorithms of evolution systems, stress-update algorithms and consistent linearization of updating schemes		
Intended Learning outcomes: to demonstrate		
A knowledge and understanding of:	The students understand the concepts of plasticity and viscoelasticity as important classes of inelastic material response with a wide range of engineering applications. They have obtained a detailed understanding of selected aspects of the theories of plasticity and viscoelasticity, including specific algorithmic treatments.	
an ability to: (thinking skills)	The students understand fundamental concepts material modeling.	
an ability to: (practical skills)	Write their own material routines in connection with existing codes for a variety of optimization problems using a programming language (C, Fortran or MATLAB)	
an ability to: (key skills)	Study independently; synthesize diverse informations;	
Assessment: Homework assignments, 100% from end of Term examination		
Recommended texts: Lecture Notes		

TENDERING, CONTRACTING AND PROJECT MANAGEMENT		
Credits: 6 **Term:** 3 **Compulsory**: No		
Format :	Lectures & Examples Private study	45h 120 h
Lecturer: Dr. Wolfgang Paul		
Contents:		
International contracting and the stages of project tendering and contracting: origin, definition, challenges and chances of international tendering and contracting; important aspects (project financing and payment, bonding, strategies for contractors, the role of the consultant in international contracting); the five stages of a project (pre-tendering, tendering, negotiation, implementation, winding-up); legal requirements (important documents, contract forms, conditions of contract). Methods of cost calculation: the first method deals with “cost calculation through the bid sum“ and the following items are explored- important definitions of terms of cost calculation, relationship between costs and produced quantity, principle of allocation of costs, basic elements of costs and quantities. Costs are classified into the following types: direct costs, site overhead costs, general overhead costs, risk and profit. An important differentiation is made between labour, material, equipment costs, costs for subcontracting. “Cost calculation with predetermined charges“ will be introduced as an alternative method of cost calculation. Examples for the different steps of the whole cost calculation will be performed and practised. Upon completion of the course, the students should be able to work out a technical and commercial proposal based on a systematic cost calculation (inclusive of basic knowledge for tendering strategies) as well as to evaluate tender proposals on behalf of a client.		
Intended Learning outcomes: to demonstrate		
1. A knowledge and understanding of:	How to deal with international project contracts and the various aspects related to this field. They can evaluate contracts and know the principles of cost calculation as the basis for tendering.	
2. an ability to: (thinking skills)	Appreciating the importance and differences between direct costs, site overhead costs, general overhead costs, risk and profit.	
3. an ability to: 4. (practical skills)	Methods of systematic cost calculation with predetermined charges.	
5. an ability to: 6. (key skills)	International contracting and tendering, project planning with international focus.	
Assessment: Written Examination (120 minutes).		
Recommended texts: Lecture notes		

PROJECT PLANNING AND FINANCING		
Credits: 6 **Term:** 3 **Compulsory**: No		
Format :	Lectures & Examples Private study	45h 120 h
Lecturer: Dr. habil. Kurt von Rabenau		
Contents:		
Project Planning and Appraisal (Summer Semester) : Comprehensive introduction into planning and appraisal of infrastructure projects. Importance of pre-screening, pre-feasibility and feasibility studies, project appraisal (financial analysis), project appraisal (economic cost benefit analysis), evaluation of project alternatives, financial viability of projects, 2 case studies based on existing feasibility studies, prepared for KfW, Logframe analysis (tool for consistent planning & risk coverage). **Project Financing, Implementation and Final Evaluation (Winter Semester):** Comprehensive introduction into financing, implementation, monitoring, and final evaluation of infrastructure projects. Requirements of external financing, external and internal sources of financing, Private sector participation for project financing and operation (BOT models), Private sector participation for operation and maintenance, important steps of project implementation (implementation consultant, terms of reference, tender, contract of goods and services), supervision, monitoring, disbursement of funds, final evaluation.		
Intended Learning outcomes: to demonstrate		
7. A knowledge and understanding of:	How to plan and to appraise, infrastructure projects in order to prepare projects themselves or to evaluate project proposals (e.g. feasibility studies) prepared by consultants. Special focus is laid upon long-term-aspects (operation and maintenance and organization of project executing agency).	
8. an ability to: (thinking skills)	How to evaluate project proposals, using tools for execution and implementation of strategies.	
9. an ability to: 10. (practical skills)	Entrepreneurship skills, project management, feasibility studies, using tools for Logframe analysis.	
11. an ability to: 12. (key skills)	study independently; use library resources; effectively take notes and manage working time.	
Assessment: Written Examination (120 minutes).		
Recommended texts: Script, Damodaran, Aswath: Corporate Finance- Theory and Practice		