SUBJECT SPECIFICATION

1. BASIC DATA

1.1. Title

NONLINEAR MECHANICS

1.2. Code

BMEEOTMMN-2

1.3. Type

module with associated contact hours

1.4. Contact hours

- lectures: 2 hours/week
- seminars/exercise classes: 1 hours/week

1.5. Evaluation

examination

1.6. Credits

4

1.7. Coordinator

Dr. Imre Bojtár, full professor (@: bojtar.imre@epito.bme.hu)

1.8. Department

Department of Structural Mechanics (http://www.epito.bme.hu/me)

1.9. Website

http://www.epito.bme.hu/BMEEOTMMN-2

1.10. Language of instruction

Hungarian and English

1.11. Curriculum requirements

- compulsory in the specialization in Numerical Modeling of the Structural engineering (MSc) programme
- elective in the Structural engineering (MSc) programme

1.12. Prerequisites

- Recommended subjects
  - BMEEOTMAS41: Strength of Materials
- Exclusive subjects
  Advanced Mechanics (BMEEOTMMST9, BMEEOTMMST1)

1.13. Effective date

from 1 September 2017.

2. OBJECTIVES AND LEARNING OUTCOMES

2.1. Objectives

The subject is the continuation of the Strength of Materials subjects taught in the Civil Engineering BSc programme on the expansion and the generalization of its linear models. Its two main goals are:
A./ the students will become acquainted with the approaches of nonlinear mechanics, its variables used in theoretical and numerical modeling, and the principal equations required for the formulation of nonlinear mechanical problems. The application of various nonlinear strain and stress tensors is analysed, furthermore the origination of the equations in the form of a general boundary and/or initial value problem or as a variational problem formthe most important types of engineering structures.
B./ The second important goal is to get to know the theoretical background required for the - primarly finite element - analysis of nonlinear problems, with an emphasis on the tehoretical and practical differences between the linear and nonlinear analysis.

2.2. Learning outcomes

Upon successful completion of this subject, the student:

A. Knowledge
1. knows the advanced decription methods of nonlinear mechanics, the important mathematical operations,
2. is familiar with the various deformation, strain and stress tensors, their calculation methods and the parity between them,
3. knows the strong and weak formulation of the basic mechanical equations,
4. understands the theoretical background of the energy and work principles, their advantages in application,
5. is familiar with the origination of multifield variational principles, and the basic of their numerical application,
6. understands the most important solution techniques of nonlinear mechanical problems, including the calculaion of basic problems of classic mechanics,
7. has an overview of the physical basis of thermoplastic and elasto-plastic material models,
8. understands the methods for the formulation of the equations of the beam-, plate- and shell modells for the linear and nonlinear analysis, including the calculation method of the curcature tensor of arbitrary shells,

B. Skills
1. calculates the deformation gradient and characterize the rigid-body-like rotation and stretch of an arbitrary structure from the data taken from a numerical model,
2. calculates the strains and stresses in a given point of a structure from the measured laboratory data, even for large displacements,
3. individually creates nonlinear elastic, elasto-plastic and time-dependent material models,
4. effectively uses the various work and energy theorems,
5. calculates the stresses of a beam with general cross section from torsion with various models,
6. calculates the stresses of a beam with general cross section from bending and shear with various models,
7. uses the higher-order shear models for the numerical analysis of beams and plates,
8. calculates the curvature tnsor of a curved shell structure,
9. processes and critically interprets the literature,
10. uses clear and precise expressions in the oral and written communication,

C. Attitudes
1. endeavors to discover and routinely use the tools necessary to the problem solving of nonlinear mechanical problems,
2. endeavors to the precise and error-free problem solving,
3. aspires to prepare a well-organized documentation in writings, and pursues the precise self-expression in oral communication

D. Autonomy and responsibility
1. independently carries out the conceptual and numerical analysis of nonlinear engineering problems, and the selection of the tools,
2. is open to accept well-founded critical comments.

2.3. Methods

Lectures, exercises, oral and written communication, application of IT tools and technologies, optional individual assignment, optional processing of selected research papers.

2.4. Course outline

week	Topics of lectures and exercise classes
1.	Basic concepts, equations of motion, calculation of gradient tensor
2.	Strain tensors in various bases
3.	Principal values of stretches and strains. Polar decomposition of the gradient tensor. Calculation of strains in curvilinear base.
4.	Calculation of various stress tensors. Pairs of strain- and stress tensors according to thermodynamics.
5.	Material model, the model af a thermoelastic materials.
6.	Characterization of plastic and viscous material behaviour.
7.	Basic equations of mechanics, strong and weak formulations
8.	Work theorems, reciprocal theorems.
9.	Multifield variational principles, various versions energy theorems.
10.	Connection between the formulation as a boundary value problem and as a variational problem, main solution methods of mechanical problems.
11.	Stress functions and their applications.
12.	Mechanical models of linear/curved beams with shear/bending deformation.
13.	Calculation of curvatures of surface. Mechanical models of plates.
14.	Mechanical models of shells used for linear and nonlinear problems.

The above programme is tentative and subject to changes due to calendar variations and other reasons specific to the actual semester. Consult the effective detailed course schedule of the course on the subject website.

2.5. Study materials

- Lecture notes: Bojtár Imre: Advanced Mechanics
- Online materials: selected journal papers and books.

2.6. Other information

1. Attendance at lectures is mandatory.
2. Students attending tests/exams must not communicate with others without explicit permission during the test/exam, and must not have an electronic or non-electronic device capable of communication switched on.

2.7. Consultation

The instructors are available for consultation during their office hours, as advertised on the department website. Special appointments can be requested via e-mail: bojtar.imre@epito.bme.hu.

SUBJECT REQUIREMENTS

3. ASSESSMENT AND EVALUATION OF THE LEARNING OUTCOMES

3.1. General rules

- Evaluation of learning outcomes described in Section 2.2. is based on two mid-term written checks, one homework and a oral exam in the examination period.
- The duration of each mid-term test is 60 minutes.
- The dates of checks and the deadlines of homeworks can be found in the "Detailed semester schedule" on the website of the subject.

3.2. Assessment methods

Evaluation form (type)	abbrev.	assessed learning outcomes (2.2)
1st mid-term test (summarizing check)	**ZH1**	A 1-4, B 1-4, B 10, C 2
2nd mid-term test (summarizing check)	**ZH2**	A 5-8, B 5-10, C 2
Homework (summarizing check)	**HF**	A 1-8, B 1-8, C 1-3, D 1-2
Oral exam (summarizing check)	**V**	A 1-8, B 1-8, C 1-3, D 1-2

Dates and deadlines of evaluations can be found in the „Detailed course schedule” on the subject’s website.

3.3. Evaluation system

Evaluation	score
ZH1 (1st mid-term test)	25%
ZH2 (2nd mid-term test)	25%
HF (Homework)	15%
sum in the midterm	40%
V (oral exam)	60%
Sum	100%

Only the best mid-term test result is considered (that is why the sum of the weights above is not 100%).

3.4. Requirement and validity of signature

- A minimum presence of 70% is required to gain a signature
- Signature and eligibility for the exam is granted if the best mid-term test result is not less than 50%.
- A signature obtained previously will remain valid at a re-registering for the subject, but the new results are to be considered nevertheless.

3.5. Grading system

- In the case of complying with the requirements on attendance the results are determined as follows.
- No requirements are made on the successfulness of the midterm-tests.
- The midterm result is computed by the results of the best mid-term tests and of the homework.
- The semester result is computed by the weighted average A of the best mid-term test, the homework, and the oral exam as in section 3.3.:

Average	grade
85%≤A	5 (Excellent)
72,5%≤A<85%	4 (Good)
65%≤A<72,5%	3 (Satisfactory)
50%≤A<65%	2 (Passed)
A<50%	1 (Failed)

3.6. Retake and repeat

- Mid-term tests cannot be retaken in this subject.
- There is no second retake in this subject.
- Homeworks not submitted by deadline can be submitted after paying late fee until the end of the last class of the semester.

3.7. Estimated workload

activity	hours/semester
contact lesson	**28x2=56**
preparation for lessons during the semester	**28x1=28**
preparation for the checks	**2x6=12**
preparation of homework	**12**
preparation for oral exam	**12**
in total	**120**

3.8. Effective date

from 1 September 2017.