MŰEGYETEM 1782
Budapest University of Technology and Economics
Faculty of Mechanical Engineering

BULLETIN

for the Mechanical Engineering Modelling Master of Science (M.Sc.) students beginning their studies in the first semester of the 2013/2014 academic year

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The updated version can be downloaded from:
http://www.gpk.bme.hu/MSc/
Mesterszakok

CONTENT

1. FOREWORD

The Budapest University of Technology and Economics Faculty of Mechanical Engineering has educated engineers since 1871.

In 2005, according to the objectives of the European Higher Education Area, the Faculty of Mechanical Engineering introduced four Bachelor of Science (B.Sc.) programs. These four programs are the following: mechanical engineering, energetics engineering, mechatronics engineering and industrial design engineering. These programs are seven semesters long.

The Master of Science (M.Sc.) programs offered at The Budapest University of Technology and Economics (BME) are not restricted to those who received their B.Sc. diplomas in engineering at BME. These programs are open to all students who receive diplomas in mechanical engineering, mechatronics engineering or transportation engineering at any of the Hungarian or foreign institutions of higher education. The entrance requirements of the programs have been defined in a way which also allows someone having a B.Sc. in another engineering area, physics, mathematics or computer science to join the M.Sc. programs while fulfilling a few additional requirements.

I hope and believe that by partaking in these programs you will become engineers who are able to fully live up to the expectations of the late BME professor Géza Á. Pattantyús, who stated:

> **"In order to responsibly practice as a professional engineer, you not only need to have specialized knowledge, but also need to be well rounded, have strength of character, have ethical values and be responsible."**

I wish you all good health and the willpower to succeed in your studies.

Dr. Tibor Czigány

Dean

2. THE MECHANICAL ENGINEERING MODELLING PROGRAM AND THE MECHANICAL ENGINEERING PROFESSION

For years the Hungarian machine industry and machine manufacturing industry have grown at rates many times greater than Hungary's own economic growth. The boost of the export market has played a key factor in this growth, as the machine industry makes up a dominant part of Hungary's export market.

The classical 5 year mechanical engineering programs offered at BME always offered specialization opportunities geared toward research and development, putting emphasis on applying the newest theoretical, experimental and computational techniques in those areas of mechanical engineering which required a deep understanding of mathematics, solid and fluid mechanics, thermodynamics, computer science or electronics.

In the 1990-s, while the structure and ownership of the Hungarian industries were changing, a reduction in the percentage of mechanical engineers working in design, development and research was detected, while an increase in the percentage working in operations, servicing, sales and software development accompanied this change. At the same time, there were signs of certain western European companies establishing design and development divisions in Hungary, as well as hiring young Hungarian engineers temporarily, who would then return to Hungary in order to set up small divisions and institutions. These groups have expressed a need for engineers specializing in mechanical engineering modelling, who are able to use complex software packages used in development work and who understand the theoretical backgrounds on which these software packages are based, while also requiring that they be able to communicate, research the available literature and complete their everyday tasks in English.

According to a survey conducted by the Hungarian Institute for Economic and Enterprise Research in 2008, the Faculty of Mechanical Engineering of the Budapest University of Technology and Economics is the most prestigious engineering institution of higher education in Hungary today [http://www.gvi.hu/data/research/diploma_2008_felsointrang.pdf]. A good measure of the international acknowledgement of a mechanical engineering diploma from BME is the number of alumni who now work internationally and the increase in the number of western European and American students choosing to study abroad at BME or even completing an entire program of study here. There is a continuous stream of students arriving from all corners of the world. It can therefore be said that, due to its interdisciplinary character and English courses, this program offers an ideal opportunity to distinguished guest lecturers and foreign students.

3. THE TWO CYCLE EDUCATIONAL SYSTEM

Today, we hear more and more about the formation of a "European Higher Education Area". The plan is to accomplish this according to the necessary procedures and changes written down in the "Bologna Declaration", which is referred to as the Bologna Process. One of the goals which are laid down in this declaration is the introduction of a multi cycle educational system, which will be used in order to compare and accept diplomas from different institutions of higher education.

Hungary has joined this process. Most of the higher education institutions of technology introduced the two cycle educational system in 2005, and many aspects formerly associated with the structure of higher education in Hungary have changed. Until now, students finishing secondary school needed to decide whether they wanted to continue their higher education in a vocational university, which offered a more practical training, or a university, which offered a deeper theoretical background.

In the new educational system, after seven semesters (acquiring 210 credit points), students finishing the first cycle (B.Sc. degree), have received enough practical training to work in the industry, also receiving the necessary certificates to do so. On the other hand, those who would rather specialize in a certain area are equipped with sufficient theoretical knowledge to continue on. At the end of this second cycle, after four semesters (acquiring 120 credit points), they can acquire the M.Sc. diploma. The top students then have the opportunity to continue on towards a PhD, which consists of an additional six semesters (acquiring 180 credit points, taking the final exams and defending their PhD thesis) of study.

While in theory a B.Sc. diploma from any institution has the same value, it is not trivial which institution a student chooses if he or she wishes to continue on after the first cycle. In Hungary, just as in any part of the world, the quality of the education provided changes from institution to institution. For this reason, students receiving their B.Sc. degrees from a university will be provided with specialized knowledge which will most definitely help them in successfully completing the second cycle. It is only natural though – based on the nature of the first cycle –, that they will also be provided with the practical skills which are necessary for someone not wishing to continue their education to successfully find work in the industry.

In developing the B.Sc. curriculum, the Faculty of Mechanical Engineering at BME aspired to provide students with a high level of education, as has always been the tradition at BME, which is up-to-date and competitive from a European point of view.

The Faculty of Mechanical Engineering changed to the two cycle educational system in 2005. In the first cycle, according to the curriculum, students study for seven semesters, receiving a B.Sc. diploma upon acquiring 210 credit points, completing a final project and passing the final exams, if they have a C-type intermediate language exam.

After finishing the first cycle – those students who have finished with adequate results – can continue on to the second cycle with a chance to possibly receive state funding to cover the tuition.

In order to successfully finish the new two cycle educational program, it is required that students take a different approach. After finishing one or two semesters the students need to make a career plan based on their results, experiences and interests, and make decisions based on these. Deciding which area to specialize in, whether to continue on after the first cycle or instead to work in the industry are a few of these decisions which need to be made.

Measure of the educational work load

In working toward the M.Sc. diploma, the students need to complete four semesters, during which they need to acquire 120 credit points. This averages out to be about 30 credit points per semester.

In order to receive the credit points, one needs to fulfill the requirements of the given subject.

Measure of the academic achievements

Beside the grades received for each subject, the weighted grade point average serves as a measure of the academic achievements:

$$K = \frac{\sum (grade \times credit\ points)}{\sum credit\ points}.$$

The stipend index shows how a student performed in a given semester both in quantity and quality as compared to an expected optimum level:

$$stipend\ \ index = \frac{\sum (acquired\ credit\ points\ \times grade)}{30}.$$

It can be seen from the equation that the results are divided by the 30 credit points which are prescribed in the curriculum. Therefore a student taking more subjects in a semester will have a better stipend index, while a student taking less than the prescribed 30 credit points worth of classes will not be able to receive a 5.0 in the given semester. Only those classes are taken into consideration in the calculation for which the requirements were fulfilled.

The grade point average is calculated the same way as the weighted grade point average, the only difference being that all the completed semesters are taken into account and not only the present ones.

3.1. Rules regarding the credit system

The prerequisite for entering the M.Sc. program – other than a successful admission – is that the student needs to have completed certain subject matter. Since students applying for the Mechanical Engineering Modelling M.Sc. program can come from many different undergraduate programs, there might be some who do not meet these "prerequisites". The completion of some "supplemental" subjects will be required of them. Due to the flexibility associated with the credit system, these subjects can be taken together with the M.Sc. subjects, or in a separate semester. The „supplemental" subject requirements must be fulfilled within two semesters of beginning the program.

During the M.Sc. program a total of 120 credit points must be attained from the M.Sc. level courses prescribed in the curriculum. The credit system gives students the opportunity to do this at their own pace and along one of many paths toward the M.Sc. degree.

Enrollment in subjects is very flexible due to the credit system. The M.Sc. program does propose certain prerequisite classes which help in making the subject easier to accomplish and are therefore highly advised.

In the M.Sc. curriculum there are 33 credit points which are dedicated to the final project. This can be completed in two semesters (Major Project and Final Project). It is a prerequisite that at least 54 credit points as well as any "supplemental" subjects be completed prior to beginning the Major Project. In order to begin the Final Project, it is required that the student finish – excluding the elective subjects – 79 credit points worth of the M.Sc. subjects found in the curriculum.

Students partaking in the M.Sc. program can take the final exams after finishing all the subjects required by the curriculum as well as acquiring the right to sit for the final exams, a certificate which has its own criteria. Diplomas are only received after the final exams have been successfully passed and the language exam requirements have been met.

The language exam requirements are regulated by ordinance 15/2006.IV.3 OM, which states that the M.Sc. degree can only be received if the student has a B2 (formerly known as intermediate "C") language exam or an equivalent high school diploma in any modern foreign language for which literature is available in the given area of study.

Students who have not fulfilled the internship requirements of the given program of study in advance need to do so during the M.Sc. program. The internship needs to be at least six weeks long, as regulated in the curriculum of the given institution of higher education. Each student must take the subject "Indurstrial Practice" at the MSc level. Internship fulfilled in the course of the BSc formation is automatically acknowledged and the signature will be registered in Neptun before the examination period.

Any subject which is offered at the M.Sc. level can be taken as an elective subject.

All detailed rules regarding matters of study can be found in the Code of Studies and Exams of BME (BME TVSZ). All matters regarding fees and allowances can be found in the Code of Fees and Allowances (BME TJSZ).

4. FACULTIES AND DEPARTMENTS PARTAKING IN THE EDUCATIONAL PROGRAM

An educational unit is any establishment, usually in the form of a department or, yet more seldom, an institution, established in order to study and teach a certain area of science. The following departments partake in the educational program:

Faculty	Code	Department	Address
GE		**Faculty of Mechanical Engineering**	
GE	EN	Department of Energy Engineering	D bldg. 3rd floor
GE	FO	Department of Mechatronics, Optics and Mechanical Engineering Informatics (Additional old department codes: MI)	E bldg. 3rd floor D bldg. 4th floor
GE	GT	Department of Manufacturing Science and Engineering	E bldg. 2nd floor
GE	GE	Department of Machine and Industrial Product Design (Additional old department codes: TT)	K bldg. mezzanine-floor. 79 Mg bldg. 1st floor
GE	VG	Department of Hydrodynamic Systems	D bldg. 3rd floor
GE	MM	Department of Applied Mechanics	MM bldg. 1st floor
GE	MT	Department of Materials Science and Engineering	MT bldg. ground floor
GE	ÁT	Department of Fluid Mechanics	AE bldg.
GT		**Faculty of Economic and Social Sciences**	
GT	20	Institute of Business Sciences	T bldg. 4th floor
TE		**Faculty of Natural Sciences**	
		Mathematical Institute:	
TE	90	Department of Differential Equations	H bldg. 4th floor
		Institute of Physics:	
TE	12	Department of Atomic Physics	F bldg. 3rd stairwell mezzanine-floor
VI		**Faculty of Electrical Engineering and Informatics**	
VI	AU	Department of Automation and Applied Informatics	V2 bldg. 4th floor

5. THE CODE SYSTEM OF THE SUBJECTS

The following sections of the bulletin will present the subjects in the following manner. As an example let us look at the following subject:

COUPLED PROBLEMS IN MECHANICS - BMEGEMMMW07

Contact hours: 1+0+1 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Kovács Ádám, associate prof.

Topics:

Diffusion problems: thermomechanical, chemomechanical, hygromechanical fields. Coupled piezo-electromechanical equations. Fluid-structure interaction. Smart structures, micro-electromechanical systems. Contact stresses in deformable bodies. Finite element modelling. Mesh coupling. Partitioned analysis. Case studies.

Recommended literature:

Zienkiewicz, O.C.; Taylor, R.L., Finite Element Method (5th Edition) Volume 1 - The Basis, Elsevier, 2000.

Hearn, E.J., Mechanics of Materials, Volume 2 - The Mechanics of Elastic and Plastic Deformation of Solids and Structural Materials (3rd Edition), Elsevier, 1997.

Every subject has an identification code, in this case it is:

BME	GE	MM	MW	07
university	faculty	department	M – M.Sc. program, W - Mech. Eng. Mod.	2 digit code

The first part of the code contains BME, the code of the Faculty of Mechanical Engineering and that of the department. The names, addresses and codes of the different departments are given in a table found in chapter 4. The next two characters depict the M.Sc. program (M) and the Mechanical Engineering Modelling M.Sc. program (W). The last two characters are used to differentiate between a department's different subjects. Additional information can be found in the 2nd and 3rd rows:

- *Contact hours*, followed by their distribution: the first being the lecture, the second the seminar, and the third the laboratory practice;
- *Credits*, these are received upon completion of the subject requirements (in the example there are „3" credit points);
- *Requirement*, can be either examination or practical mark (based on work done during the semester);
- *Responsible.* Notice: this is not necessarily the lecturer of the subject.
- This is followed by a concise summary of the subject matter and a list of recommended literature.

6. CURRICULUM OF THE MECHANICAL ENGINEERING MODELLING M.SC. PROGRAM

List of abbreviations appearing in the curriculum:

lect – lecture
sem - seminar (classroom practice)
lab - laboratory practice
cr – credits
p/e/s - practical mark/exam/signature

Beginning of the term: spring				Mechanical Engineering Modelling	Beginning of the term: fall			
1. Semester (spring)	2. Semester (fall)	3. Semester (spring)	4. Semester (fall)		1. Semester (fall)	2. Semester (spring)	3. Semester (fall)	4. Semester (spring)
lect / sem / lab / cr / p/e/s				**Subjects**	lect / sem / lab / cr / p/e/s			
				Basic Subjects				
4/2/0/8/e				Differential Equations and Numerical Methods		4/2/0/8/e		
	3/1/0/4/e			Laser Physics	3/1/0/4/e			
3/0/0/4/e				Analytical Mechanics		3/0/0/4/e		
3/0/0/4/e				Advanced Fluid Mechanics		3/0/0/4/e		
2/1/0/4/e				Advanced Thermodynamics		2/1/0/4/e		
	2/0/1/4/e			Electronics	2/0/1/4/e			
	2/1/0/4/e			Advanced Control and Informatics	2/1/0/4/e			
				Special Compulsory Subjects				
	2/1/0/4/e			Machine Design and Production Technology	2/1/0/4/e			
	3/0/1/5/p			Major Compulsory Subject I	3/0/1/5/p			
2/1/0/5/p				Major Compulsory Subject II		2/1/0/5/p		
		0/0/11/14/p		Major Project			0/0/11/14/p	
				Special Subjects				
		1/0/2/3/e		Major Elective Subject I				1/0/2/3/e
			1/0/1/3/e	Major Elective Subject II			1/0/1/3/e	
			1/1/0/3/p	Major Elective Subject III			1/1/0/3/p	
3/0/1/5/p				Minor Compulsory Subject I		3/0/1/5/p		
	2/1/0/5/p			Minor Compulsory Subject II	2/1/0/5/p			
		1/0/1/3/e		Minor Elective Subject I				1/0/1/3/e
		2/0/0/3/p		Minor Elective Subject II				2/0/0/3/p
			0/0/15/19/s	Final Project				0/0/15/19/s
				Subjects in Economics				
	3/0/0/5/p			Management	3/0/0/5/p			
		3/0/0/5/p		Marketing				3/0/0/5/p
				Elective Subjects				
		1/1/0/3/p	1/0/1/3/p	Further Elective Subjects			1/0/1/3/p	1/1/0/3/p
				Criterion				
				Industrial Practice				
				Total				
30	31	31	28	Total credit points	31	30	23	36
17/4/1/22	17/4/2/23	8/0/15/23	3/2/16/21	Total contact hours	17/4/2/23	17/4/1/22	3/2/16/21	8/0/15/23
4	4	2	1	Number of Exams	4	4	1	2

6.1. *Modules available in the Mechanical Engineering Modelling M.Sc. program*

Two specialization modules (major and minor) need to be picked from the five which are available in the BME Mechanical Engineering Modelling M.Sc. program. Though there are five modules available, it is not guaranteed that all of them will be started every year. It is not possible to start a module with less than 6 applicants. Therefore it is important that all students decide which modules they would like to study at the beginning of the program. Therefore, the students decide which modules will be started. Those students who choose modules which end up not having enough applicants can choose to either change over to a different module which is being started, or to wait until the desired module is started in a future semester. The students should make a decision about the major module before the application. However, the major and minor modules can be reversed before the students choose the major/final project topics. The module in which the students perform the major and final projects becomes the "major" one, the other remains the "minor" one.

6.1.1. FLUID MECHANICS MODULE

Beginning of the term: spring				**Fluid Mechanics**	Beginning of the term: fall			
1. Semester (spring)	**2. Semester (fall)**	**3. Semester (spring)**	**4. Semester (fall)**		**1. Semester (fall)**	**2. Semester (spring)**	**3. Semester (fall)**	**4. Semester (spring)**
lect / sem / lab / cr / p/e/s				**Subjects**	lect / sem / lab / cr / p/e/s			
				Basic Subjects				
3/0/0/4/e				Advanced Fluid Mechanics		3/0/0/4/e		
				Special subjects / Major or Minor Compulsory Subjects				
	2/2/0/5/p			Computational Fluid Dynamics	2/2/0/5/p			
2/1/1/5/p				Flow Measurements		2/1/1/5/p		
		0/0/11/14/p		Major Project			0/0/11/14/p	
				Special subjects / Major or Minor Elective Subjects				
		1/1/0/3/ p		Large-Eddy Simulation in Mechanical Engineering				1/1/0/3/p
		2/0/0/3/p		Fluid Technical Process Modelling				2/0/0/3/p
		1/1/0/3/p		Multiphase and Reactive Flow Modelling				1/1/0/3/p
		2/0/0/3/p		Unsteady Flows in Pipe Networks				2/0/0/3/p
		2/0/0/3/p		Measurement Techniques and Signal Processing				2/0/0/3/p
			2/0/1/3/p	Building Aerodynamics			2/0/1/3/p	
			2/0/0/3/p	Aerodynamics and its Application for Vehicles			2/0/0/3/p	
			2/0/0/3/p	Advanced Technical Acoustics and Measurement Techniques			2/0/0/3/p	
			2/0/0/3/p	Hemodynamics			2/0/0/3/p	
			2/0/0/3/p	Flow Stability			2/0/0/3/p	
			2/0/0/3/p	Theoretical Acoustics			2/0/0/3/p	
			0/0/15/19/s	Final project				0/0/15/19/s

6.1.2. Solid Mechanics module

Beginning of the term: spring				Solid Mechanics	Beginning of the term: fall			
1. Semester (spring)	2. Semester (fall)	3. Semester (spring)	4. Semester (fall)		1. Semester (fall)	2. Semester (spring)	3. Semester (fall)	4. Semester (spring)
lect / sem / lab / cr / p/e/s				**Subjects**	lect / sem / lab / cr / p/e/s			
				Basic Subjects				
3/0/0/4/e				Analytical Mechanics		3/0/0/4/e		
				Special subjects / Major or Minor Compulsory Subjects				
2/0/2/5/p				Finite Element Analysis		2/0/2/5/p		
	2/1/0/5/p			Continuum Mechanics	2/1/0/5/p			
		0/0/11/14/p		Major Project			0/0/11/14/p	
				Special subjects / Major or Minor Elective Subjects				
		1/1/0/3/p		Elasticity and Plasticity				1/1/0/3/p
		1/1/0/3/e		Nonlinear Vibrations				1/1/0/3/e
		1/0/1/3/p		Coupled Problems in Mechanics				1/0/1/3/p
			1/1/0/3/p	Mechanisms			1/1/0/3/p	
			1/1/0/3/e	Beam Structures			1/1/0/3/e	
			1/0/1/3/p	Experimental Methods in Solid Mechanics			1/0/1/3/p	
			0/0/15/19/s	Final project				0/0/15/19/s

6.1.3. Thermal Engineering module

Beginning of the term: spring				Themal Engineering	Beginning of the term: fall			
1. Semester (spring)	2. Semester (fall)	3. Semester (spring)	4. Semester (fall)		1. Semester (fall)	2. Semester (spring)	3. Semester (fall)	4. Semester (spring)
lect / sem / lab / cr / p/e/s				**Subjects**	lect / sem / lab / cr / p/e/s			
				Basic Subjects				
2/1/0/4/e				Advanced Thermodynamics		2/1/0/4/e		
				Special subjects / Major or Minor Compulsory Subjects				
	2/1/1/5/p			Combustion Technology	2/1/1/5/p			
1/0/3/5/p				Measurements in Thermal Engineering		1/0/3/5/p		
		0/0/11/14/p		Major Project			0/0/11/14/p	
				Special subjects / Major or Minor Elective Subjects				
		2/1/0/3/e		Energy Conversion Processes and its Equipment				2/1/0/3/e
		1/0/2/3/p		Simulation of Energy Engineering Systems				1/0/2/3/p
		2/0/1/3/p		Thermal Physics				2/0/1/3/p
			2/0/1/3/p	Thermo-Mechanics			2/0/1/3/p	
			2/1/0/3/p	Steam and Gas Turbines			2/1/0/3/p	
			3/1/0/3/e	Thermo-Hydraulics			3/1/0/3/e	
			0/0/15/19/s	Final project				0/0/15/19/s

6.1.4. Design and Technology module

Beginning of the term: spring				Design and Technology	Beginning of the term: fall			
1. Semester (spring)	2. Semester (fall)	3. Semester (spring)	4. Semester (fall)		1. Semester (fall)	2. Semester (spring)	3. Semester (fall)	4. Semester (spring)
lect / sem / lab / cr / p/e/s				**Subjects**	lect / sem / lab / cr / p/e/s			
				Special subjects / Major or Minor Compulsory Subjects				
	2/1/0/4/e			Machine Design and Production Technology	2/1/0/4/e			
	2/0/1/5/p			Product Modelling	2/0/1/5/p			
1/0/3/5/p				Advanced Manufacturing		1/0/3/5/p		
		0/0/11/14/p		Major Project			0/0/11/14/p	
				Special subjects / Major or Minor Elective Subjects				
		1/0/2/4/p		CAD Technology				1/0/2/4/p
		2/0/0/3/e		Materials Science				2/0/0/3/e
		1/0/2/4/p		Structural Analysis				1/0/2/4/p
			1/1/0/3/p	Process Planning			1/1/0/3/p	
			1/1/0/3/p	NC Machine Tools			1/1/0/3/p	
			2/0/0/3/e	Fatigue and Fracture			2/0/0/3/e	
			0/0/15/19/s	Final project				0/0/15/19/s

6.1.5. Robotics module

Beginning of the term: spring				Robotics	Beginning of the term: fall			
1. Semester (spring)	2. Semester (fall)	3. Semester (spring)	4. Semester (fall)		1. Semester (fall)	2. Semester (spring)	3. Semester (fall)	4. Semester (spring)
lect / sem / lab / cr / p/e/s				**Subjects**	lect / sem / lab / cr / p/e/s			
				Basic subjects				
	2/1/0/4/e			Advanced Control and Informatics	2/1/0/4/e			
				Special subjects / Major or Minor Compulsory Subjects				
	2/0/1/5/p			Robot Constructions	2/0/1/5/p			
2/1/0/5/p				Robot Control		2/1/0/5/p		
		0/0/11/14/p		Major Project			0/0/11/14/p	
				Special subjects / Major or Minor Elective Subjects				
		3/0/0/3/e		Production Planning and Control				3/0/0/3/e
		2/0/1/3/p		Software Technologies				2/0/1/3/p
		1/1/0/3/e		Artificial Neural Networks and Hybrid Systems				1/1/0/3/e
		1/0/2/3/p		Robot Programming				1/0/2/3/p
			2/0/0/3/p	Simulation of CNC Machines and Robots			2/0/0/3/p	
			1/1/1/3/p	Assembly			1/1/1/3/p	
			1/1/0/3/p	Special Robots and Robot Applications			1/1/0/3/p	
			1/1/0/3/p	Microelectronics in Control			1/1/0/3/p	
			0/0/15/19/s	Final project				0/0/15/19/s

6.2. Subjects of the final exam

The subjects for the final exam need to be chosen from the major module subjects (totaling 16 cr):

- Major Compulsory Subject I, 5 cr
- Major Compulsory Subject II, 5 cr
- Major Elective Subject, 3 cr
- Major Elective Subject, 3 cr

7. INTRODUCTION OF THE MECHANICAL ENGINEERING MODELLING M.SC. SUBJECTS

7.1. *Basic Subjects*

MATHEMATICS MI - DIFFERENTIAL EQUATIONS AND NUMERICAL METHODS - BMETE90MX46

Contact hours: 4+2+0 **Credits:** 8 **Requirement:** examination
Responsible: Dr. Paál György

First order ordinary differential equations, difference between linear and nonlinear equations. The existence and uniqueness theorem. Modelling with first order equations. First order difference equations. Introduction into numerical methods: explicit, implicit schemes, stability problems, multi-step methods. Second order linear ordinary differential equations, homogeneous and nonhomogeneous equations. Series solutions of second order equations, ordinary points, regular singular points, Bessel equations. Systems of first order ordinary differential equations. Classification of equilibrium points; Introduction into Lyapunov stability; almost linear systems. Classification of abstract vector spaces, inner product spaces, generalized Fourier series. Orthogonal function systems, trigonometric Fourier series, Gibbs phenomenon. Sturm-Liouville problems, Vibrating string, heat transfer problem in Cartesian and in cylindrical coordinates, Bessel functions, vibrating drumhead.

Recommended literature:

1. W. E. Boyce and R. C. DiPrima: Elementary differential equations and boundary value problems. John Wiley and Sons Inc.
2. M. A. Pinsky: Partial Differential Equations and Boundary Value Problems with Applications. McGraw-Hill, 1998.

LASER PHYSICS - BMETE12MX00

Contact hours: 3+1+0 **Credits:** 4 **Requirement:** examination
Responsible: Dr. Lőrincz Emőke, associate prof.

Theory of laser oscillation, characteristics of laser light, laser applications. Interaction of photons with atoms, line-broadening mechanisms, coherent amplification, optical resonator, conditions of continous wave and transient laser oscillation. Properties of laser beams: monochromacity, coherence, directionality, brightness. Laser types: solid-state, semiconductor, gas, fluid (dye) and miscellaneous. Laser applications: industrial, medical, communication, measurement technique.

Recommended literature:

1. Saleh B. E. A, Teich M. C.: Fundamentals of Photonics, John Wiley & Sons, Inc. 1991.
2. Svelto O.: Principles of Lasers, Springer, 1998.
3. LIA Handbook of Laser Materials Processing, ed. in chief John F. Ready, Laser Institute of America, 2001

ANALYTICAL MECHANICS - BMEGEMMMW01

Contact hours: 3+0+0 **Credits:** 4 **Requirement:** examination

Responsible: Dr. Stépán Gábor, professor

Classification of mechanical systems of assemble of particles and rigid bodies. Classifications of constraints, geometric and kinematic constraints. Virtual velocity, virtual power and general force. Lagrangian equations of the second kind. Examples. Approximations of the natural frequencies of continua. Longitudinal, torsional and bending vibrations of beams, standing wave and travelling wave solutions. Strings. Vibrations of rotors, critical speed of shafts, Campbell diagram.

Recommended literature:

1. Gantmacher, F.: Lectures in analytical mechanics, Mir Publishers, Moscow, 1975.
2. Hand-Finch, Analytical Mechanics, Cambridge Univ. Press, 2004.

ADVANCED FLUID MECHANICS - BMEGEÁTMW01

Contact hours: 3+0+0 **Credits:** 4 **Requirement:** examination

Responsible: Dr. Kristóf Gergely, associate prof.

Main objective of the subject is to understand the physical phenomena occurring in various flow categories of technical relevance and to gain practical knowledge in analyzing flow phenomena. Detailed thematic description of the subject: Overview of the fundaments of fluid mechanics. Vorticity transport equation. Potential flows, solution methods based on analytical solutions. Percolation, Darcy flow. Wells. Boundary layers. Similarity solutions for laminar and turbulent boundary layers. Overview of computational fluid dynamics (CFD). Turbulence models. Fundaments of gas dynamics. Wave phenomena. Izentropic flow, Prandtl-Meyer expansion, moving expansion waves. Normal shock waves, oblique shock waves, wave reflection. Jets. Open surface flows, channel flows. Pipe networks. Transient flow in pipelines. Atmospheric flows.

Recommended literature:

1. Lecture handouts: www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMW01
2. Lamb, H.: Hydrodynamics, 1932.
3. Schlichting, H.: Boundary Layer Theory, 1955.
4. Shapiro A.H: The Dynamics and Thermodynamics of Compressible Fluid Flow, 1953.
5. Streeter, V.L. & Wylie, E.B: Fluid Mechanics, McGraw-Hill, 1975.
6. Ferziger, J.H. & Peric, M.: Computational Methods for Fluid Dynamics, Springer, ISBN 3-540-42074-6, 2002.

ADVANCED THERMODYNAMICS - BMEGEENMWAT

Contact hours: 2+1+0 **Credits:** 4 **Requirement:** examination

Responsible: Dr. Gróf Gyula, associate prof.

General model structure of thermodynamics. Equation of state (gases, liquids and solids). Laws of thermodynamics. System of body and environment, heat, work, reservoirs, extended systems. Irreversible processes, availability, exergy analysis, entropy generation minimization. Multi component phase equilibrium. Reaction equilibrium. Basics of non equilibrium thermodynamics. Second law. Linear laws. Onsager reciprocity. Local equilibrium. Heat conduction, diffusion, cross effects. Rheology. Poynting-Thomson body.

Recommended literature:

1. Bejan: Advanced Engineering Thermodynamics, J. Wiley & Sons, 2006
2. Honig: Thermodynamics, Academic Press San Diego, 1999

ELECTRONICS - BMEVIAUM001

Contact hours: 2+0+1 **Credits:** 4 **Requirement:** examination

Responsible: Dr. Rakos Balázs, assistant prof.

Electronic components: Diode, Zener diode, Transistors (bipolar and field effect transistors), Common-emmiter characteristics.
Discrete circuits: Emitter-follower circuit, Amplification, Impedance matching, Series connection of amplifier stages, Feedback.
Integrated circuits: Operational amplifier, Mathematical operations, Wave shape generation, Function generation, Filters, Power supply.
Recommended literature:

1. Charles Fraster and John Milne: Integrated Electrical and Electronics Engineering for Mechanical Engineers, McGraw-Hill Book Company, London, 1994.
2. Animated Lecture notes in electronics form: http://elektro.get.bme.hu/
3. James W. Nilsson: Electric Circuits, Addison-Wesley Company, Massachusets 1990.
4. J. Millman, A. Grabel: Microelectronics, 1987.
5. Nagy I., J. Megyeri: Analog elektronika (Analog Electronics), Tankönyvkiadó, Budapest, 1992, J4-1081/10

ADVANCED CONTROL AND INFORMATICS - BMEGEMIMW01

Contact hours: 2+1+0 **Credits:** 4 **Requirement:** examination

Responsible: Dr. Korondi Péter, professor

Short overview of the classical design methods of PID controllers. Sensors and actuators of an internet based motion control system. Implementation of discrete time PID controller for an internet based motion control system. Linear Time Invariant systems. Controllability and Observability. Canonical forms, the Kalman decomposition, realization theory, minimal realizations. Sate feedback control: pole placement, Linear Quadratic Regulator (LQR), Linear Quadratic Gaussian (LQG) control designs. Discrete Time Systems. Robust Control, H infinity control, Sliding Mode Control, Implementation of sliding control desing for an internet based motion control system.
Recommended literature:

1. Peter Korondi "Selected chapters of Advanced Control" digital textbook
2. "DC Servo Motor Control via Internet", Student exercise manual, Version 1.2
3. "Motion Control and Telemanipulation, Robotics" animated teaching material http://dind.mogi.bme.hu/animation/

MACHINE DESIGN AND PRODUCTION TECHNOLOGY - BMEGEGEMW01

(Special Compulsory Subject)

Contact hours: 2+1+0 **Credits:** 4 **Requirement:** examination

Responsible: Dr. Váradi Károly, professor

Machine design: Design principles and methods. Requirements. Modern design techniques. Structural behavior and modeling. Design of frame structures. Polymer and composite components. Load transfer between engineering components. Structural optimization (object function, design variables, constrains, shape and size optimization).

Production: Machine-tools and equipment, devices and fixtures, kinematics, machining principles, production procedures and processes, production volume, batches and series. Manufacturability and tooling criteria, preliminary conditions and production analysis, methods of sequencing operations, production planning and scheduling. Production management (TQC and JIT), automated production; cellular manufacturing, machining centres and robots. Product data and technical document management (PDM, TDM), engineering changes and production workflow management (CE, ECM).

Recommended literature:

1. Grabowski, H.: Universal design theory, Shaker Verlag, Aachen, 1998.
2. Ullman, D.G.: The mechanical design process, McGraw Hill, 1997.
3. Dym, C.L.: Engineering design, Cambridge University Press, 1994.
4. Kalpakjian, Schmid: Manufacturing Engineering and Technology, Prentice-Hall Inc. Publ. 2001, ISBN 0-201-36131-0

7.2. Subjects of the Fluid Mechanics module

7.2.1. SPECIAL SUBJECTS / MAJOR OR MINOR COMPULSORY SUBJECTS

COMPUTATIONAL FLUID DYNAMICS - BMEGEÁTMW02

Contact hours: 2+2+0 **Credits:** 5 **Requirement:** practical mark

Responsible: Dr. Kristóf Gergely, associate prof.

Main objective of the subject is providing sufficient theoretical background and practical knowledge for professional CFD engineers. Detailed thematic description of the subject: Derivation of differentiation and integration schemes; accuracy and stability. Approximation of surface integrals, divergence and gradient terms in finite volume method. Numerical fluxes, upwinding schemes. Solution methods for the pressure-velocity coupling: psi-omega method, pressure correction methods. Solution of linear systems of algebraic equations with special respect to the iterative Poisson solvers. Characteristics of the governing equations of compressible fluid flows. Method of characteristics. Finite volume method with explicit time marching scheme for compressible fluid flows. Numerical mesh: quality requirements and advanced meshing techniques. Main characteristics of the turbulence. Length scales. Overview of turbulent models: Reynolds-averaged models, transport equation of turbulent kinetic energy, two-equation models. Analyses of the sources of errors and uncertainties. Error estimation. Simulation exercises in computer laboratory.

Recommended literature:

1. Lecture handouts: www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMW02
2. Ferziger, J.H. & Peric, M.: Computational Methods for Fluid Dynamics, ISBN 3-540-42074-6, Springer-Verlag, Berlin, 2002.

FLOW MEASUREMENTS - BMEGEÁTMW03

Contact hours: 2+1+1 **Credits:** 5 **Requirement:** practical mark

Responsible: Dr. Vad János, associate prof.

Main objective of the subject is getting acquainted with the measurement principles, application areas, advantages and limitations of various flow measuring techniques applied in industrial practice as well as in research&development related laboratory activities. Detailed thematic description of the subject: Practical / industrial aspects of flow measurements. Measurement of temporal mean pressures: static, total, dynamic. Probes and methods. Manometers. Pressure-based measurement of velocity magnitude and direction. Anemometers, thermal probes. Measurement of unsteady pressures. Temperature measurements. Hot wire anemometry. Laser optical flow diagnostics: Laser Doppler Anemometry (LDA), Phase Doppler Anemometry (PDA), Particle Image Velocimetry (PIV). Flow visualization. Flow rate measurements with use of contraction elements and deduced from velocity data. Comparison. Flowmeters: ultrasonic, MHD, capacitive cross-correlation technique, Coriolis, vortex, rotameter, turbine, volumetric. Industrial case studies. Collaboration of measurement technique and computational simulation. Laboratory exercise.

Recommended literature:

1. Vad, J. (2008), *Advanced flow measurements.* Műegyetemi Kiadó, 45085. ISBN 978 963 420 951 5.
2. Lecture handouts: www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMW03

MAJOR PROJECT IN FLUID MECHANICS - BMEGEÁTMWD1

Contact hours: 0+0+11 **Credits:** 14 **Requirement:** practical mark

Responsible: Dr. Suda Jenő M., assistant prof.

The aim of the course is to develop and enhance the capability for complex problem solving of the students under advisory management of the so-called Evaluation Team. The student's supervisor and two advisors form the Evaluation Team (ET).

Detailed thematic description of the subject: various experimental and/or numerical (CFD) major project proposals are announced by the supervisors well before the registration week. The major project proposals are defined as being complex problems both for the 3rd and further on the 4th semester, since they are to be continued in course of the Final Project (BMEGEÁTMWD2) in the 4th semester. The findings of the complex, two-semester long project will be summarised in the final Master (MSc) Thesis.

In course of the Major Project and further on the Final Project the student will work on one selected challenging problem of fluid mechanics.

1st ET meeting on the 4th week: 1st project presentation by the student

2nd ET meeting on the 8th week: 2nd project presentation by the student

3rd ET meeting on the 14th week: 3rd project presentation by the student

On the 15th week: submission of the major Project Report in printed and electronic format.

Evaluation Team members assess the students work, presentations & report.

Note, that for students taking the major in Fluid Mechanics of Mechanical Engineering Modelling MSc various Major Project proposals are announced also by the Dept. Hydrodynamic Systems (under their own subject code BMEGEVGMWD1).

Recommended literature:

1. Preliminary literature survey is essential part of the project start, but reference literature will be provided by the project leader / advisors, too.
2. Further information: www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMWD1

7.2.2. SPECIAL SUBJECTS / MAJOR OR MINOR ELECTIVE SUBJECTS

LARGE-EDDY SIMULATION IN MECHANICAL ENGINEERING - BMEGEÁTMW05

Contact hours: 1+1+0 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Kristóf Gergely, associate prof.

The main objective of the subject is to get familiar with the concept of Large-Eddy Simulation and its widely used techniques. A secondary objective is to gain knowledge about post-processing techniques specially suited for instantaneous and steady 3D flow data. Applications from turbulent heat transfer and noise production will be shown.

Detailed thematic description of the subject: Motivations why to use Large-Eddy Simulation (LES). Filtering of the incompressible Navier-Stokes equations, basic filter properties. Numerical requirements of the simulation. Subgrid scale modelling approaches. Interacting error dynamics. Practical aspect of the simulation (domain time and mesh requirements). Special LES boundary conditions: inlet turbulence generation. Hybrid and zonal LES/RANS approaches. Postprocessing of LES results: flow topology description, vortex detection methods. Case studies: internal cooling channel, flow around an airfoil, near field of a jet.

Recommended literature:

1. Lesieur, M.; Métais, O. & Comte, P. Large-Eddy Simulations of Turbulence Cambridge University Press, 2005
2. Pope, S.B. Turbulent Flows, Cambridge University Press, 2000
3. Sagaut, P. Large Eddy Simulation for incompressible Flows. An Introduction Springer, 2002
4. Geurts, B.J. Elements of direct and large-eddy simulation R.T. Edwards, Inc., 2003
5. Lecture handouts: www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMW05

FLUID TECHNICAL PROCESS MODELLING - BMEGEÁTMW06

Contact hours: 2+0+0 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Vad János, associate prof.

The main objective of the subject is to get acquainted with various industrial fields, with special regard to ones based on fluid mechanical processes. Obtainment of skill in recognition and solution of industry-related problems, on the basis of real case studies.

Detailed thematic description of the subject: Case studies from various fields of industry regarding problem solution related to fluid flow technology. Outline of the technological process, problem setting. Practical aspects of problem setting. Error analysis. Field work: on-site measurements and additional studies. Simulation case studies. Interactive solution of industry-related diagnostic problems. Proposals for elimination of the problem and their justification. Future remarks.

Recommended literature:

1. Vad, J. (2008), Advanced flow measurements. Műegyetemi Kiadó, 45085. ISBN 978 963 420 951 5.
2. Lecture handouts: www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMW06

MULTIPHASE AND REACTIVE FLOW MODELLING - BMEGEÁTMW07

Contact hours: 1+1+0 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Szabó K. Gábor, associate prof.

The main objective of the subject is to understand the physical phenomena occurring in fluid systems with more than one chemical components or more than one phases. Familiarization with special measurement techniques used in such systems. Outlining the concepts of possible theoretical models and numerical modelling, understanding limitations due to restricted range of validity and computational resources. Detailed studying of models used in some typical engineering applications.

Detailed thematic description of the subject: Physical phenomena, major concepts, definitions and modelling strategies. Lagrangian vs. Eulerian description. Equilibrium vs. non-equilibrium models. Dimensionless numbers. Modelling free surface and fluid-fluid interfaces. Bubble growth and collapse. Gravity and capillary waves. Dispersed particle transport. Flow regimes and model options. Sedimentation and fall-out. Flow regimes in vertical, horizontal and inclined pipes. Closure relations. Advanced two-phase flow instrumentation. Phase change and heat transfer in single-component systems: boiling, cavitation, condensation. Related heat transport problems and industrial applications. Phase interactions: particle agglomeration and break-up. Modelling chemical reactions: flames, combustion models, atmospheric reactions. Computational Multi-Fluid Mechanics (CMFD): general methods and limitations, usage of general purpose computational fluid dynamics codes, design of specialized target software. Applications in power generation, hydrocarbon and chemical industry.

Recommended literature:

1. Lecture handouts: www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMW07
2. C. Crowe, M. Sommerfield, and Yutaka Tsuji. Multiphase Flows with Droplets and Particles. CRC Press, 1998.
3. D. Gidaspow. Multiphase Flow and Fluidization. Academic Press, Boston, 1994.

UNSTEADY FLOWS IN PIPE NETWORKS - BMEGEVGMW02

Contact hours: 2+0+0 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Halász Gábor, professor

Structure of piping systems. Description of steady flow as initial condition for computing transient operation. Derivation of the basic equation system for 1D unsteady flow in pipe sections. Solution methods: method of characteristics, implicit methods. Boundary condition treatment. Modelling gas release and cavitation. Open channel flow modelling. Possibilities to protect the system from dangerous pressure surges, check valves, air chambers. Electrodynamic analogy, the impedance method.

Recommended literature:

1. Wylie, E.B. – Streeter, V.L.: Fluid transients in systems, McGraw-Hill, 1993
2. Fox, R.W. – McDonald, A.T.:Introduction to Fluid Mechanics, John Wiley & Sons, 1994

MEASUREMENT TECHNIQUES AND SIGNAL PROCESSING - BMEGEMIMW07

Contact hours: 2+0+0 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Lipovszki György associate professor

Signals and systems in the time and frequency domains. Mathematical methods in signal processing. Methods of digital data acquisition and signal processing.

Measurement errors and probability. Signal to noise ratio improvement. Analogue signal filtering and processing. Filtering and processing of digital signals.

Noisy periodic signals, stochastic signals, amplitude density function, cross- and autocorrelation. Statistical methods of signal processing: non-parametric and parametric statistical tests.

Recommended literature:

1. Sydenham, P. H.: Handbook of Measurement Science, Vol. 1 and 2., J. Wiley 1982.
2. J. S. Bendat – A.G. Piersol: Random Data (Analysis and Measurement Procedures) John Wiley

&Sons Inc. 2000.

BUILDING AERODYNAMICS - BMEGEÁTMW08

Contact hours: 2+0+1 **Credits:** 3 **Requirement:** practical mark
Responsible: Dr. Lajos Tamás, professor

The main objective of the subject is to extend the knowledge of students in aerodynamics in general and in building aerodynamics and transport of pollutants in particular as well as to contribute to development of skills of students in practical use of theoretical knowledge.

Detailed thematic description of the subject: Structure and properties of atmospheric boundary layer, characteristics of wind. Bluff-body aerodynamics: boundary layer separation, characteristics of separated flows, vortices, their effects on the flow description of complex 3-dimensional flow fields. Arising and characterisation of wind forces. Wind and structure interaction, aero-elasticity. Building aerodynamics (e.g. buildings, chimneys and towers). Bridge aerodynamics. Computational wind engineering. Wind codes and standards: fundamentals and philosophy (ASCE and EUROCODE). Wind loading estimates based on wind tunnel measurements, numerical simulation and standards. Dispersion of pollutants in urban environment, effect of buildings on dispersion. Relationship between wind effects and ventilation of halls and rooms in building. Experimental wind tunnel measurement and CFD case studies.

Recommended literature:

1. Simiu, E and Scanlan, RH.: Wind Effects on Structures: Fundamentals and Applications to Design, Wiley-Interscience, 1996 (third edition)
2. Lawson, T.: Building Aerodynamics, ISBN 1-86094-187-7, Imperial College Press, 2001
3. Lajos T.: Az áramlástan alapjai (2009) ISBN 9789630663823
4. Lecture handouts: www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMW08

AERODYNAMICS AND ITS APPLICATION FOR VEHICLES - BMEGEÁTMW09

Contact hours: 2+0+0 **Credits:** 3 **Requirement:** practical mark
Responsible: Dr. Lajos Tamás, professor

The main objective of the subject is to extend the knowledge of students in Aerodynamics in general and in Vehicle Aerodynamics in particular as well as to contribute to development of skills of students in practical use of theoretical knowledge.

Detailed thematic description of the subject: Streamlined body aerodynamics: theory of airfoils, streamlined bodies of revolution, streamlined bodies of finite extension. Compressibility effects, flows with variable air density. Impact of aerodynamics on aircrafts at subsonic and supersonic speeds. Bluff body aerodynamics: boundary layer separation, characteristics of separated flows, vortices, their effects on the flow and their detection techniques, description of complex 3-dimensional flow fields. Principles of aerodynamic design and optimization of passenger car bodies, trucks and buses. Basics of flow control: control techniques without flow separation (turbulators, boundary layer blow down and suction), and with flow separation (high lift devices, vortex generators, winglets). STOL aircraft, delta wing aircraft, Formula 1 race car aerodynamics.

Recommended literature:

1. A.M. Keuthe, C-Y Chow: Foundations of Aerodynamics. John Wiley & Sons, Inc. 1998. ISBN 0-471-12919-4
2. W. H. Hucho: Aerodynamik des Automobils. Springer-Verlag, 1999. ISBN: 3-540-62160-1
3. T. Lajos: Az áramlástan alapjai (2009) ISBN: 9789630663823
4. Web page: www.aerodyn.org

5. Web page: http://www.aeromech.usyd.edu.au/aero/aerodyn.html
6. Lecture handouts: www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMW09

ADVANCED TECHNICAL ACOUSTICS AND MEASUREMENT TECHNIQUES - BMEGEÁTMW10

Contact hours: 2+0+0 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Vad János, associate prof.

The main objective of the subject is to extend the knowledge in technical acoustics and measurement techniques with the help of presentation of acoustic design and measurement methods, common in the engineering practise.

Detailed thematic description of the subject: The ray theory, sound propagation in non-homogeneous media. Sound propagation in duct and higher order modes. Spherical waves, and the point monopole, dipole and quadrupole sound sources. The flow generated sound, Lighthill's acoustic analogy and the inhomogeneous wave equation. Attenuation of sound waves. Acoustic measurements, microphones, analysers, calibrators, intensity measurement, anechoic and reverberating chambers.

Recommended literature:

1. A.P.Dowling, J.E.Foowcs Williams: Sound and Sources of Sound, Ellis Horwood Limited, 1983, ISBN 0-85312-400-0
2. Leo L. Beranek: Noise and Vibration Control, Institute of Noise Control Engineering,1988,ISBN 0-9622072-0-9
3. Lecture handouts: www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMW10

HEMODYNAMICS - BMEGEVGMW06

Contact hours: 2+0+0 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Pandula Zoltán, assistant professor

Fluid mechanical and structural questions of the arterial system. Models and methods for the description of blood flow in blood vessels (fluid mechanical and mechanical equations), numerical solution of the equations. Major invasive and non-invasive methods of blood flow and blood pressure measurements, methods for numerical modelling of blood pressure. Characteristic physiological quantities and their influence in hemodynamics.

Recommended literature:

1. Nichols, W. W., O'Rourke, M. F. (2005): McDonald's Blood flow in arteries, (Oxford University Press), ISBN 0 340 80941 8
2. Streeter, V. L., Wylie, E. B. (1967): Hydraulic Transients, (McGraw-Hill Book Company)

FLOW STABILITY - BMEGEVGMW07

Contact hours: 2+0+0 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Paál György, associate professor

Mechanisms of instability, basic concepts of stability theory, Kelvin-Helmholz instability. Basics of linear stability for continuous and discrete systems with examples; stability of discretization techniques (explicit and implicit Euler technique, Runge-Kutta schemes) and linear stability analysis of surge in turbomachines. The Hopf bifurcation theorem with application to turbomachinery. Galerkin projection and its applications. Lorenz equations; derivation (Rayleigh-Bénard convection), linear and nonlinear stability, interpretation of the bifurcation diagram. Loss of stability of parallel inviscid and viscous flows. Instability of duct flow, jet flow, boundary layer. Thermal and centrifugal instability. Uniform asymptotic approximations.

Recommended literature:

1. P. G. Drazin: Introduction to Hydrodynamic Stability. Cambridge University Press, 2002
2. P. G. Drazin, W. H. Reid: Hydrodynamic Stability. Cambridge University Press, 2004
3. J. Guckenheimer, P. Holmes: Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vector Fields. Applied Mathematical Sciences, Vol. 42, Springer-Verlag, New York, 1983, ISBN 0-3879-0819-6

THEORETICAL ACOUSTICS - BMEGEVGMW08

Contact hours: 2+0+0 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Paál György, associate professor

Properties of monopole, dipole and quadrupole sound sources. Lighthill's theory. Excited vibrating string. Green functions in free space and compact Green functions in the vicinity of bodies. Reciprocity theorem. The Kirchhoff vector. Examples. The vortex sound equation. Examples.

Recommended literature:

1. P. M. Morse and K. U. Ingard: Theoretical Acoustics, McGrow-Hill, New York, 1976
2. M. S. Howe: Theory of vortex sound. Cambridge University Press, 2003

FINAL PROJECT IN FLUID MECHANICS - BMEGEÁTMWD2

Contact hours: 0+0+15 **Credits:** 19 **Requirement:** signature

Responsible: Dr. Suda Jenő M., assistant prof.

The aim of the course is to develop and enhance the capability for complex problem solving of the students under advisory management of their project supervisor and two advisors. Each student's project is guided by the project supervisor and depending on the problem -if applicable- by two advisors. They form the so-called Evaluation Team (ET). ET meetings are organized 3 times per semester.

Detailed thematic description of the subject: Several experimental and/or numerical (CFD) final project proposals will be announced by the project leaders well before the registration week. The final project proposals are defined as being complex problems of mainly fluid mechanics, usually they must be the continuation of the major projects' proposals. The students will work on complex problems proposed in the 3rd semester in course of the Major Project (BMEGEÁTMWD1). The Major Project and Final Project together serves as a two-semester project that results in the Master (MSc) Thesis of the student. In course of the Final Project one single student will work on the selected challenging problem of fluid mechanics.

1st ET meeting: on the 4th week: 1st project presentation by the student

2nd ET meeting: on the 8th week: 2nd project presentation by the student

3rd ET meeting: on the 14th week: 3rd final project presentation by the student

On the 15th week: submission of the final Project Report (ie. the Master Thesis) in printed and electronic format. Evaluation team members assess the students work, presentations & report.

Note, that for students taking the Major Project that was announced by the Dept. Hydrodynamic Systems (under subject code BMEGEVGMWD1) must continue their project in course of the Final Project announced also by the Dept. Hydrodynamic Systems (under code BMEGEVGMWD2).

Recommended literature:

1. Preliminary literature survey is essential part of the project start, but reference literature will be provided by the project leader / advisors, too.
2. Further informations: www.ara.bme.hu/oktatas/tantargy/NEPTUN/BMEGEATMWD2

7.3. Subjects of the Solid Mechanics module

7.3.1. SPECIAL SUBJECTS / MAJOR OR MINOR COMPULSORY SUBJECTS

FINITE ELEMENT ANALYSIS - BMEGEMMMW02

Contact hours: 2+0+2 **Credits:** 5 **Requirement:** practical mark

Responsible: Dr. Szekrényes András, associate prof.

The basic equations of linear elasticity, Green-Lagrange strain tensor. Shear effect in beams, Timoshenko beam theory. FE formulation of Timoshenko beams. Isoparametric Timoshenko beam element, shear locking, interpolation with exact nodal solution, examples. Isoparametric quadrilateral elements, shape functions, Jacobian matrix and determinant, excessive distortion. Numerical integration, Gaussian rule. Stiffness matrix and load vectors of quadrilaterals. Stability of linear elastic systems, the method of Trefftz. FE formulation of stability problems, geometric stiffness matrix. Buckling, lateral buckling and lateral-torsional buckling of slender beams with symmetric cross section, examples. Torsion of straight prismatic beams. Second order dynamics, buckling and vibration of beams. Dynamic stability analysis. Method of weighted residuals, Galerkin FEM. FE solution of nonlinear static structural problems, full and modified Newton-Raphson methods. Tangent stiffness matrix. FE solution of damped forced vibrations, Duhamel integral. Direct time integration, central difference method, Newmark's method, numerical examples. Modelling examples in ANSYS including elasticity, plasticity, elastic stability, dynamics and thermomechanics problems.

Recommended literature:

1. Bathe, K. J. Finite Element Procedures. 1996 Prentice Hall, Simon & Schuster / A Viacom Company, Upper Saddle River, New Jersey 07458.
2. Madenci, E., Guven, I. The Finite Element Method and Applications in Engineering Using ANSYS. 2006 Springer Science + Business Media Inc., The University of Arizona.
3. Felippa, C.A.: Introduction to Finite Element Methods. PDF documents are available at the website of the Technische Universität München, Computational Mechanics, M.Sc. course: http://www.st.bv.tum.de/index.html?2/content/teaching/fem1/fem1.html

CONTINUUM MECHANICS - BMEGEMMMW03

Contact hours: 2+1+0 **Credits:** 5 **Requirement:** practical mark

Responsible: Dr. Szabó László, professor

Historical overview. Mathematical background (Cartesian tensors, properties and representations, invariants, tensor fields, derivatives of tensors, integral theorems). Kinematics. Bodies and configurations. Lagrangian and Eulerian description of a continuum. Deformation gradient. Deformation of arc, surface and volume elements. Deformation and strain tensors. Polar decomposition: stretch and rotation tensors. Displacement, infinitesimal strain and rotation. Material time derivative. Rates of deformation: stretching and spin tensors. Conservation of mass, continuity equation. Concept of force. Cauchy's theorem on the existence of stress. First and second Piola-Kirchhoff stress tensors. Linear momentum principle. Equation of motion. Angular momentum principle. Balance of energy: concepts on stress power, rate of work, internal energy. First and second law of thermodynamics. Clausius-Duhem inequality. Dissipation function. Constitutive theory. Principles of determinism and local action. Material frame indifference and objectivity. Constitutive equations of elasticity, viscoelasticity, plasticity and fluid mechanics.

Recommended literature:

1. Malvern, L. E., Introduction to the Mechanics of a Continuous Medium, Prentice Hall, 1969.
2. Holzapfel, G., Nonlinear Solids Mechanics. A Continuum Approach for Engineering. John Wiley

& Sons, New York, 2000.
3. Béda, Gy., Kozák, I., Verhás, J., Continuum Mechanics, Akadémiai Könyvkiadó, Budapest, 1998.

MAJOR PROJECT IN SOLID MECHANICS - BMEGEMMMWD1

Contact hours: 0+0+11 **Credits:** 14 **Requirement:** practical mark
Responsible: Dr. Szekrényes András, associate prof.

The Major Project subject is dedicated to the preparation of the first half of the MSc thesis. Each student must choose a proposal and a supervisor or supervisors. The proposals are available at the websites of the department or they can be requested from the professors in the course of a personal communication. The aim of the subject is to develop and enhance the problem solving capability of the students under advisory management of their supervisor. The requirement is a practical mark at the end of the semester, which is determined entirely by the supervisor.
Recommended literature: It depends on the topic of the project.

7.3.2. SPECIAL SUBJECTS / MAJOR OR MINOR ELECTIVE SUBJECTS

ELASTICITY AND PLASTICITY - BMEGEMMMW05

Contact hours: 1+1+0 **Credits:** 3 **Requirement:** practical mark
Responsible: Dr. Szabó László, professor

Elasticity: Covers vector and tensor analysis, indicial notation. Displacements and small strains. Compatibility of strain. Theory of stress. Principle stresses. Generalized Hooke's law. Strain energy function. Isotropy and anisotropy. Equilibrium equations. Problems in plane stress and plane strain. Airy stress function. Torsion of prismatic bars. Thick-walled tube, rotating disk. Principle of virtual work. Rayleigh-Ritz methods. Introduction to the finite element method. Truss and beam elements. *Plasticity:* Reviews stress and strain deviators, invariants and distortional energy. Principal and octahedral stresses and strains. Tresca and von Mises yield criteria. Yield surface and Haigh-Westergaard stress space. Lode's stress parameters. Subsequent yield surface. Prandtl-Reuss relations. Work and strain hardening. Isotropic and kinematic hardening rules. Incremental and deformation theories. Time-dependent deformations: visco-elasticity, elasto-viscoplasticity and creep. Simple truss. Bending of straight beams. Thick-walled tube. Plasticity equations in finite element methods. Stress updating algorithms and consistent tangent modulus.
Recommended literature:
1. Khan, A. S., Huang, S., Continuum Theory of Plasticity, John Wiley & Sons, New York, 1995.
2. Malvern, L. E., Introduction to the Mechanics of a Continuous Medium, Prentice Hall, 1969.
3. Chen, W. F., Han, D. J., Plasticity for Structural Engineers, Springer-Verlag, Berlin, 1988.
4. Simo, J.C., Hughes, T. R. J., Computational Inelasticity, Springer-Verlag, New York, 1997.

NONLINEAR VIBRATIONS - BMEGEMMMW06

Contact hours: 1+1+0 **Credits:** 3 **Requirement:** examination
Responsible: Dr. Stépán Gábor, professor

Phase plane analysis of single degree-of-freedom nonlinear systems. Construction of trajectories and their analysis in case of conservative nonlinear systems. The effect of nonlinear damping. Harmonic excitation of nonlinear mechanical systems, resonance in nonlinear systems. Self-excited vibrations. Liénard and Bendixson criteria for limit cycles. Hopf bifurcations. Chaotic oscillations.

Recommended literature:

1. Ludvig Gy., Gépek dinamikája (Dynamics of Machines), Műszaki Könykiadó, Budapest, 1989.
2. Rand R., Topics in Nonlinear Dynamics with Computer Algebra, Gordon and Breach, 1994.
3. Lesser M., The Analysis of Complex Nonlinear Mechanical Systems, World Scientific, 1996.

COUPLED PROBLEMS IN MECHANICS - BMEGEMMMW07

Contact hours: 1+0+1 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Kovács Ádám, associate prof.

Diffusion problems: thermomechanical, chemomechanical, hygromechanical fields. Coupled piezo-electromechanical equations. Fluid-structure interaction. Smart structures, micro-electromechanical systems. Contact stresses in deformable bodies. Finite element modelling. Mesh coupling. Partitioned analysis. Case studies.

Recommended literature:

1. Zienkiewicz, O.C.; Taylor, R.L., Finite Element Method (5th Edition) Volume 1 - The Basis, Elsevier, 2000.
2. Hearn, E.J., Mechanics of Materials, Volume 2 - The Mechanics of Elastic and Plastic Deformation of Solids and Structural Materials (3rd Edition), Elsevier, 1997.

MECHANISMS - BMEGEMMMW08

Contact hours: 1+1+0 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Bende Margit, assistant prof.

Structural analysis of kinematical chains: degrees of freedom, groups, six-bar chains, equivalent chains. Straight-line guide. Four-bar linkage. Planar motion: relative centers of zero velocity, transmission, theorem of Kennedy. Curvature theory: fixed and moving centrodes, envelopes, inflexion circle, return circle, centre of curvature, theorem of Euler-Savary, theorem of Bobillier. Acceleration field. Cams and gears.

Recommended literature:

1. Sandor, G.N., Erdman, A.G.: Advanced Mechanism Design: Analysis and Synthesis. Prentice Hall, 1984.

BEAM STRUCTURES - BMEGEMMMW09

Contact hours: 1+1+0 **Credits:** 3 **Requirement:** examination

Responsible: Dr. Szekrényes András, associate prof.

Free torsion of prismatic bars. Saint-Venant warping function, stress function. Torsion of single- and multi-cell sections. Warping of thin-walled sections, the sector area function, definition of shear center. Transformation of the sector area function. Examples for open and closed sections. Constrained torsion of thin-walled open sections, bimoment, torsional warping constant, warping statical moment. Governing differential equations and boundary conditions under constrained torsion, examples: U-section and I-section beams. Demonstration of the importance of shear center through real models. Shearing of thin-walled section beams. Shear-warp function, shear center. Engineering solutions for open and closed sections, modified statical moments. Advanced analysis of built-in beams, Saint-Venant effect and Winkler elastic foundation models. The basic theory of sandwich beams with thin and thick facesheets.

Definition of anti-plane core materials, application examples.

Recommended literature:

1. Wempner G., Mechanics of Solids with Applications to Thin Bodies, Sijthoff & Noordhoff, Alphen aan den Rijn, The Netherlands, Rockville, Maryland, USA 1981.
2. Ponomarjov, SZ. D., Szilárdsági számítások a gépészetben (Strength Calculations in Engineering), Műszaki Könykiadó, Budapest, 1964.
3. Allen H.G. Analysis and Design of Structural Sandwich panels. Pergamon Press, Oxford, London, Edinburgh, New York, Toronto, Sydney, Paris, Braunschweig, 1969.

EXPERIMENTAL METHODS IN SOLID MECHANICS - BMEGEMMMW10

Contact hours: 1+0+1 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Szekrényes András, associate prof.

Strain measuring methods, theory and practice, strain gauges. Application to an aluminium block. Linear elastic fracture mechanics of composites, fracture model of Griffith. Manufacturing of composite specimens. Evaluation of fracture mechanical tests. Direct and indirect data reduction schemes. J-integral, improved beam theory schemes, elastic foundation beams, crack tip shear deformation in composite beams. Application of the virtual crack-closure technique. Mode-I and mode-II fracture tests. The mixed-mode bending problem. Mode partitioning in mixed-mode I/II tests. Fracture envelopes and fracture criteria. Test methods for the mode-III interlaminar fracture. Experimental equipments and measuring methods. Stability and vibration of delaminated beams.

Recommended literature:

1. Anderson T.L. Fracture Mechanics – Fundamentals and Applications. Boca Raton, London, New York, Singapore, Taylor & Francis, CRC Press, 2005
2. Adams, D.F., Carlsson, L.F., Pipes R.B. Experimental Characterization of Advanced Composite materials. Boca Raton, London, New York, Singapore, Taylor & Francis, CRC Press, 2003

FINAL PROJECT IN SOLID MECHANICS - BMEGEMMMWD2

Contact hours: 0+0+15 **Credits:** 19 **Requirement:** signature

Responsible: Dr. Szekrényes András, associate prof.

The final project subject is dedicated to prepare the second half of the MSc thesis. As the continuation of the major project, the aim of the subject is to demonstrate the ability of the student to solve high level, practical engineering problems, based on acquired knowledge in the fields of mechanical engineering. In some special cases the students can choose a different topic than that of the major project, however in this case the thesis should be prepared in the course of one semester. The projects have to be prepared by the students under the guidance of supervisors. The Final Projects include tasks in design, simulations, laboratory tests, manufacturing as well as controlling, interfacing and software tasks. The expected result is mostly a Final Report prepared according to written formal requirements. During the Final Exam, the results have to be explained in an oral presentation.

Recommended literature: It depends on the topic of the project.

7.4. Subjects of the Thermal Engineering module

7.4.1. SPECIAL SUBJECTS / MAJOR OR MINOR COMPULSORY SUBJECTS

COMBUSTION TECHNOLOGY - BMEGEENMWCT

Contact hours: 2+1+1 **Credits:** 5 **Requirement:** practical mark
Responsible: Dr. Penninger Antal, professor

Types of fuels, ultimate/proximate analysis, fuel technology, analysis methods and results, excess air factor, calorific value, stoichiometric calculation, practical analysis of combustion products. Physical parameters of combustion, reaction types, flame velocity, combustion aerodynamics; premixed and diffusion flames, atomization, pulverization, different types of burners. Fuel technology: properties of various solid, liquid and gaseous fuels. Equipment constructions. Modelling methods and techniques in combustion.

Laboratory: Flame velocity. Flame demonstrations. Emission measurement.

Recommended literature:

1. Warnatz, Jürgen: Combustion: Physical and chemical fundamentals, modeling and simulation, experiments, pollutant, Springer, 1999.
2. Kuo, Kenneth, Kuan-yun: Principles of combustion, Wiley, 2005.

MEASUREMENTS IN THERMAL ENGINEERING - BMEGEENMWM1

Contact hours: 1+0+3 **Credits:** 5 **Requirement:** practical mark
Responsible: Dr. Bereczky Ákos, associate prof.

Measurement methods and techniques of thermal processes. System - model - measurement - evaluation. State of the art data acquisition methods, systems and signal transducers. Operational and service measurements, engine diagnostics, performance characteristic. Stability and vibrations tests. Evaluation methods in data processing. Questions of safety, availability and reliability. Application of LabView graphical programming environment.

Recommended literature:

1. Lipták, G. Béla: Instrument engineers' handbook, CRC Press, 2003-2006 (Vol. 1: Process measurement and analysis, Vol. 2: Process control and optimization)
2. The measurement and automation, National Instruments Catalogue 2004.

MAJOR PROJECT IN THERMAL ENGINEERING - BMEGEENMWD1

Contact hours: 0+0+11 **Credits:** 14 **Requirement:** practical mark
Responsible: Dr. Bereczky Ákos, associate prof.

In course of the Project one student or group of 2 students will work on one selected challenging problem of mechanical engineering. Several experimental and/or numerical project proposals will be announced by the project leaders. The aim of the course is to develop and enhance the capability for complex problem solving of the students under advisory management of their project leader. At the end of each semester a written Project Report is to be submitted and the summary and findings of the investigations on the selected problem is to be presented as Project Presentation.

Recommended literature: It depends on the topic of the project.

7.4.2. SPECIAL SUBJECTS / MAJOR OR MINOR ELECTIVE SUBJECTS

ENERGY CONVERSION PROCESSES AND ITS EQUIPMENT - BMEGEENMWEE

Contact hours: 2+1+0 **Credits:** 3 **Requirement:** examination
Responsible: Dr. Penninger Antal, professor

Energy sources, demands and utilizations. Power generation. Steam cycles (superheating, reheating, regeneration, combined). Boilers and steam generators. Nuclear power stations. Combined heat and power generation. Internal combustion engines. Centralized - distributed power generation. Calculation of energy balance, software's for system planning and modelling. Environment protection.

Recommended literature:

1. Kehlhofer, Rolf: Combined-cycle gas and steam turbine power plants, Fairmont Pr. 1991.
2. Büki: Energetika (Energy management), Műegyetemi kiadó. 1997.

SIMULATION OF ENERGY ENGINEERING SYSTEMS - BMEGEENMWSE

Contact hours: 1+0+2 **Credits:** 3 **Requirement:** practical mark
Responsible: Dr. Czinder Jenő, assistant prof.

Methods of determination the dynamic models. Type of equation groups. Linear – nonlinear, distributed – concentrated parameters. Application of Matlab/Simulink interactive programming language. Case studies: simple and complex energy conversion processes. Student projects: dynamic modelling and simulation experiment.

Recommended literature:

1. Zeigler, Phillip: Theory of modelling and simulation, Academic Press, 2000.
2. http://www.mathworks.com/

THERMAL PHYSICS - BMEGEENMWTP

Contact hours: 2+0+1 **Credits:** 3 **Requirement:** practical mark
Responsible: Dr. Gróf Gyula, associate prof.

Physical backgrounds. Mechanism and models of heat conduction in solids. Non homogeneous materials. Determination methods and techniques of thermophysical properties. (Solution of inverse problem of heat conduction.) Steady state and transient methods.

Recommended literature:

1. Maglic: Compendium of thermophysical property measurement methods, Plenum, 1984.
2. Ozisik: Inverse Heat Transfer (Fundamentals and applications), Taylor&Francis, 2000

THERMO-MECHANICS - BMEGEMMMWTM

Contact hours: 2+0+1 **Credits:** 3 **Requirement:** practical mark
Responsible: Dr. Kovács Ádám, associate prof.

Temperature dependence of material properties. Governing equations of coupled thermal and mechanical fields. Thermal boundary conditions. Thermal stresses in beams, plane problems, plates, thick-walled tubes and rotating disks. Instationary heat conduction, transient thermal stresses. Numerical thermal stress analysis. Heat conductance and capacitance matrices. Computer simulation of thermal stresses.

Recommended literature:

1. Boley, B.A, Weiner, J.H.: Theory of thermal stresses. Wiley, 1960.
2. Zienkiewicz, O.C., Taylor, R.L.: The Finite Element Method. Volume 1. The Basis, Butterworth, Heinemann, 2000.

STEAM AND GAS TURBINES - BMEGEENMWTU

Contact hours: 2+1+0 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Penninger Antal, professor

Classification of turbines. Flow in nozzle. Historical notes. Principal elements. Axial flow turbines: impulse stage, reaction stage, velocity compounded stage. Losses, design considerations. Calculation of nozzles and stage parameters, power and torque. Efficiency, characteristic curves. Gas turbine cycles (inter-cooling, reheating, aircraft engines etc.). Compressors, combustion chambers, turbines, co-operation of elements. Efficiency and losses. Constructions.

Laboratory: Steam- and gas turbine demonstration and measurement.

Recommended literature:

1. P. Slyakhin: Steam turbines: Theory and design, University Press of Pacific 2005.
2. Saravanamuttoo, Rogers, Cohen: Gas turbine theory, Prentice Hall, 2001.
3. Kostyuk, Frolov: Steam and gas turbine, MIR, Moscow

THERMO-HYDRAULICS – BMETE80AE03

Contact hours: 3+1+0 **Credits:** 3 **Requirement:** examination

Responsible: Dr. Aszódi Attila, professor

Heat generation and removal in different type of nuclear reactors. General differential equation of heat conduction. Material properties of UO2. Equations of hydraulic systems. Convective heat transfer. Thermal instabilities. Natural convection. Boiling heat transfer. Boiling curve, boiling crisis. Condensation. Two phase flow patterns, flow maps. Temperature distribution in the fuel. Thermohydraulics of the coolant subchannels. Design limits of nuclear fuel. Computer codes in thermohydraulics. Fundamentals of reactor safety, the role of human factor. Design Basis Accidents. Beyond Design Basis Accidents. Relevant nuclear accidents (e.g. TMI-2, Chernobyl).

Recommended literature:

1. N. E. Todreas, M. S. Kazimi: Nuclear Systems I; Thermal hydraulic fundamentals, 1990.
2. L. S. Tong, J. Weisman: Thermal Analysis of Pressurized Water Reactors, ANS, 1996.
3. Manuscript of the lectures

FINAL PROJECT IN THERMAL ENGINEERING - BMEGEENMWD2

Contact hours: 0+0+15 **Credits:** 19 **Requirement:** signature

Responsible: Dr. Lezsovits Ferenc, assistant prof.

The aim of the subject of is to demonstrate the ability of the student to solve high level, practical engineering problems, based on acquired knowledge in the fields of mechanical engineering. The projects have to be prepared by the students under the guidance of supervisors. The Final Projects include tasks in design, simulations, laboratory tests, manufacturing as well as controlling, interfacing and software tasks. The expected result is mostly a Final Report prepared according to written formal requirements. During the Final Exam, the results have to be explained in an oral presentation.

Recommended literature: It depends on the topic of the project.

7.5. Subjects of the Design and Technology module

7.5.1. SPECIAL SUBJECTS / MAJOR OR MINOR COMPULSORY SUBJECTS

PRODUCT MODELLING - BMEGEGEMW02

Contact hours: 2+0+1 **Credits:** 5 **Requirement:** practical mark

Responsible: Dr. Váradi Károly, professor

The process of product modeling. Traditional and concurrent design. Product lifecycle management. Integrated product development. Conceptual design. Geometric models. Assembly models. Presentation techniques. Simulation models (Finite element analysis. Kinematic simulation. Behavior simulation). Optimization (object function, shape and size optimization(. Application models. Virtual prototyping. Rapid prototyping. Product costing models.

Recommended literature:

1. Horváth I., et al: Advanced Design Support, Delft University of Technology, 2005.
2. Stoll, H.W.: Product design methods and practices, Marcel Dekker, Inc., 1999.

ADVANCED MANUFACTURING - BMEGEGTMW01

Contact hours: 1+0+3 **Credits:** 5 **Requirement:** practical mark

Responsible: Dr. Mátyási Gyula, associate prof.

Mechanics of metal cutting. Machinability, advanced tool materials, coatings and tool wear. New generation of cutting tools and tool holders. Dry machinig. HSM-High speed machining. Machining of hard materials. Micro and nano technology. Reverse Engineering. Rapid Prototyping. Methods for machinig for different parts, dies and moulds. CAD/CAM and CNC structures. Monitoring of manufacturing. In-Process measuring methods in manufacturing.

Recommended literature:

1. George Schneider: Cutting tool application, Prentice Hall Inc.: http://www.prenthall.com/
2. Kalpakjian, Schmid: Manufacturing Engineering and Technology, Prentice-Hall Inc.Publ. 2001, ISBN 0-201-36131-0
3. Manufacturing, B. Benhabib, Marcel Dekker Inc., 2003, ISBN 0-8247-4273-7

MAJOR PROJECT IN DESIGN AND TECHNOLOGY - BMEGEGEMWD1

Contact hours: 0+0+11 **Credits:** 14 **Requirement:** practical mark

Responsible: Dr. Váradi Károly, professor

In course of the Project one student or group of 2 students will work on one selected challenging problem of mechanical engineering. Several experimental and/or numerical project proposals will be announced by the project leaders. The aim of the course is to develop and enhance the capability for complex problem solving of the students under advisory management of their project leader. At the end of each semester a written Project Report is to be submitted and the summary and findings of the investigations on the selected problem is to be presented as Project Presentation.

Recommended literature: It depends on the topic of the project.

7.5.2. Special subjects / Major or Minor Elective Subjects

CAD TECHNOLOGY - BMEGEGEMW04

Contact hours: 1+0+2 **Credits:** 4 **Requirement:** practical mark
Responsible: Dr. Körtélyesi Gábor, assistant prof.

CAD tools and methods in machine design. Concurrent design. Product modeling. Surface and solid models. Parametric design. Feature based design. Integrated approach. Kinematic simulation. Conceptual design. Product data management. Product lifecycle management. Distributed design approach. Virtual prototyping. Rapid prototyping.

Recommended literature:

1. Lee, K.: Principles of CAD/CAM/CAE systems, Addision-Wesley, 1999.
2. Horváth, I., et al: Advanced Design Support, Delft University of Technology, 2005.

MATERIALS SCIENCE - BMEGEMTMW01

Contact hours: 2+0+0 **Credits:** 3 **Requirement:** examination
Responsible: Dr. Mészáros István, associate prof.

Structure of crystalline solids. Imperfections in crystals. Mechanical properties of alloys. Dislocations and strengthening mechanisms. Deterioration mechanisms of engineering materials. Phase diagrams. Phase transformations. Material characterization. Non-destructive evaluation techniques. Electrical properties of metals, alloys and semicinductiors. Superconductivity. Magnetic properties. Soft and hard magnetic materials.

Recommended literature:

1. W.D. Callister: Materials Science and Engineering (John Wiely and Sons, ISBN: 0-471-32013-7)
2. R.A. Flinn, P.K. Trojan: Engineering Materials and their Applications (Houghton-Mifflin Pub. Company, ISBN: 0-395-35660-1)

STRUCTURAL ANALYSIS - BMEGEGEMW05

Contact hours: 1+0+2 **Credits:** 4 **Requirement:** practical mark
Responsible: Dr. Goda Tibor, associate prof.

Structural analysis and machine design. Fundamentals of FEM. Basic element types of professional FE systems. Preparing FE models (symmetry conditions, mesh structure, boundary conditions, loading models and material properties). Material and geometric nonlinearity. Time-dependent behaviour. Steady state and transient heat transfer. Integrated CAD-FEM systems. Structure optimization.

Recommended literature:

1. Knight, C.E.: The Finite Element Method in Mechanical Design, PWS-KENT Publishing Company, 1993.
2. Cook, R.D.: Finite Element Modeling for Stress Analysis, John Wiley & Sons, Inc. 1995.
3. Soares, C.A.M.: Computer Aided Optimal Design: Structural and Mechanical Systems, Springer-Verlag, 1987.

PROCESS PLANNING - BMEGEGTMW02

Contact hours: 1+1+0 **Credits:** 3 **Requirement:** practical mark
Responsible: Dr. Mátyási Gyula, associate prof.

Manufacturing errors, methods of prevention and elimination; surfaces of positioning, manufacturing allowances, preproduct design and selection. Manufacturing planning, machine tools and equipment, manufacturing processes and procedures, operations, electro-chemical (ecm, edm) and thermal processes, survey of surface technology. Type and Group Technology, basics of automation; cellular manufacturing, tooling criteria. Parameter planning, operation element plans, basics of primary and secondary optimisations. Adaptation, principles of NC technology; NC programming. Quality and statistical process control (SPC). Principals of computer aided manufacturing (CAM).

Recommended literature:

1. George Schneider: Cutting tool application, Prentice Hall Inc.: http://www.prenhall.com/
2. Kalpakjian, Schmid: Manufacturing Engineering and Technology, Prentice-Hall Inc.Publ. 2001, ISBN 0-201-36131-0

NC MACHINE TOOLS - BMEGEGTMW03

Contact hours: 1+1+0 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Németh István, associate professor

Fundamentals of the kinematics of machine tools and the NC technology. Structural building blocks, sensors and actuators. Spindles. Lathes and turning centres. Milling machines and machining centres. Parallel kinematics machine tools. Grinding machines. Electro discharge machines. Multi-functional machine tools. Automatic tool and workpiece changing peripheries. Mechatronic modelling, analysis, simulation and optimisation of machine tools.

Recommended literature:

1. Geoffrey Boothroyd, Winston A. Knight: Fundamentals of Machining and Machine Tools, Marcel Dekker, 1989.
2. Y. Altintas: Manufacturing Automation, Cambridge University Press, 2000.
3. S. Kalpakjian, S.R. Schmid: Manufacturing Engineering and Technology, Fourth edition, Prentice Hall Publ., 2001B. Benhabib: Manufacturing, Marcel Dekker, 2003.
4. H. Janocha (Ed.): Actuators, Springer Berlin Heidelberg New York 2004
5. L.N. López de Lacalle, A. Lamikiz (Editors): Machine Tools for High Performance Machining, Springer-Verlag London Limited, 2009

FATIGUE AND FRACTURE - BMEGEMTMW02

Contact hours: 2+0+0 **Credits:** 3 **Requirement:** examination

Responsible: Dr. Ginsztler János, professor

Cyclic loading. High cycle fatigue. S-N curve. Fatigue limit. Low cycle fatigue. Manson-Coffin relation. Neuber theory. Linear elastic fracture mechanics. Energy concept. Stress field near the crack tip. Stress intensity factor. Fracture toughness. Fracture mechanical design. Non linear fracture mechanics. Crack opening displacement. J-integral. Stable crack growth. Testing techniques. Design philosophy in nonlinear fracture mechanics. Environment assested cracking. Case studies.

Recommended literature:

1. Blumenauer-Pusch, Műszaki Törésmechanika (Applied Fracture Mechanics) Műszaki Könykiadó, Budapest, 1987.
2. Richard W. Hertzberg, Deformation and fracture mechanics of engineering materials, John Wiley & Sons,1989.
3. T.L Anderson, Fracture mechanics, CRC Press,1994.

FINAL PROJECT IN DESIGN AND TECHNOLOGY - BMEGEGEMWD2

Contact hours: 0+0+15 **Credits:** 19 **Requirement:** signature

Responsible: Dr. Váradi Károly, professor

The aim of the subject of is to demonstrate the ability of the student to solve high level, practical engineering problems, based on acquired knowledge in the fields of mechanical engineering. The projects have to be prepared by the students under the guidance of supervisors. The Final Projects include tasks in design, simulations, laboratory tests, manufacturing as well as controlling, interfacing and software tasks. The expected result is mostly a Final Report prepared according to written formal requirements. During the Final Exam, the results have to be explained in an oral presentation.

Recommended literature: It depends on the topic of the project.

7.6. Subjects of the Robotics module

7.6.1. SPECIAL SUBJECTS / MAJOR OR MINOR COMPULSORY SUBJECTS

ROBOT CONSTRUCTIONS - BMEGEGTMW04

Contact hours: 2+0+1 **Credits:** 5 **Requirement:** practical mark

Responsible: Dr. Németh István, expert

Review of robot arm structures and the rules of motions and motion simulations. The actuators as robot arm components: electromagnetic actuators (AC/DC drives), fluid power actuators, non-conventional actuators. The structure of micro robots. Sensory functions, sensors. Grasping theory and grippers. Analysis of units and components. Design and simulation of a selected robot arm unit, a gripper unit, as well as the selection of the relevant sensors.

Laboratory tests, control parameter setting on existing robot arms and grippers.

Recommended literature:

1. Actuators, (Ed.: H. Janocha), Springer Verlag, 2004, ISBN 3-540-61564-4
2. Y.Altintas, Manufacturing Automation, Cambridge University Press, 2000, ISBN 0-521-65973-6
3. B. Benhabib, Manufacturing, Marcel Dekker Inc., 2003, ISBN 0-8247-4273-7
4. Assistenzroboter, FIPA Workshop F 112 Dez.2004, Stuttgart.
5. Robot grippers (Eds: D.T. Pham, W.B. Heginbotham), IFS Publ. Ltd.-Springer Verlag, 1986, ISBN 0-948507-03-9
6. Downloads recommended from: http://www.manuf.bme.hu/

ROBOT CONTROL – BMEGEGTMW12

Contact hours: 2+1+0 **Credits:** 5 **Requirement:** practical mark

Responsible: Dr. Monostori László, professor

The course is an introduction to the basics and fundamental problems of robot modelling and control. The curriculum focuses mainly on the most common robot class in industrial use, i.e. rigid, open-chain robots, dealing with their modelling and control on the usual three levels of kinematics, differential kinematics and dynamics. Furthermore, the course gives an outlook on the properties of other robot classes (e.g., mobile robots), conditions and typical problems of practical application, and strives to provide advice concerning acquisition of further knowledge and solving problems not covered by the curriculum.

Completing the course contributes to the students learning to solve practical robotics-related modelling, planning and control problems on their own, using exact methods, while keeping up with today's quickly evolving technical knowledge.

Prerequisites: Required knowledge are the basics of control engineering, as well as a few selected areas of mechanical engineering. It is recommended to complete the mathematical curriculum prescribed for the first 4 semesters, especially with respect to the basics of linear algebra (matrix operations)

Recommended literature:

1. Lantos Béla: Robotok irányítása (Robot Control), Akadémiai Kiadó, Budapest, 1991, ISBN 963-05-6217-0
2. Mark W. Spong, M. Vidyasagar: Robot Dynamics and Control, John Wiley and Sons, 1989, ISBN 047161243X
3. Carlos Canudas de Wit, Bruno Siciliano, Georges Bastin (eds.): Theory of Robot Control, Springer-Verlag London, 1996, ISBN 3-540-76054-7

MAJOR PROJECT IN ROBOTICS - BMEGEGTMWD1

Contact hours: 0+0+11 **Credits:** 14 **Requirement:** practical mark

Responsible: Dr. Mátyási Gyula, associate prof.

In course of the Project one student or group of 2 students will work on one selected challenging problem of mechanical engineering. Several experimental and/or numerical project proposals will be announced by the project leaders. The aim of the course is to develop and enhance the capability for complex problem solving of the students under advisory management of their project leader. At the end of each semester a written Project Report is to be submitted and the summary and findings of the investigations on the selected problem is to be presented as Project Presentation.

Recommended literature: It depends on the topic of the project.

7.6.2. Special subjects / Major or Minor Elective Subjects

PRODUCTION PLANNING AND CONTROL - BMEGEGTMW10

Contact hours: 3+0+0 **Credits:** 3 **Requirement:** examination

Responsible: Dr. Monostori László, professor

The aim of subject to introduce the basic problem of the production management planing and control, the nominations, connections and methods. The topics dealing with warehouse management, for short and long time period the production and capacity planning, short time scheduling and analyzing methods of production management systems. The students became familiar with classical methods - they applied in the production management systems nowadays - and they have a view about the results of future trends. Primary importance given for the modelling and abilities of analyzing. We close a bigger series of the performance with a demonstration so the students can get a real view about the limits and development trends of production planning.

Recommended literature:

1. Hopp, W.J.; Spearman, M.L, Factory physics, Foundations of manufacturing management, Irwin, 1996.
2. Sokszorosított fejezetek az Erdélyi Ferenc (szerk.): *A technológia menedzsment informatikai eszközei; Információrendszerek. I-II. rész.* c. műből. OMFB megbízásából, a PHARE TDQM-HU-9305.01-1383.sz. projekt keretében készített tananyag Miskolc, 1997. április.
3. A tárgy előadóinak honlapjáról (http://www.sztaki.hu/~vancza) elérhető segédanyagok és az ott felsorolt irodalom (Complementary notes available at: http://www.sztaki.hu/~vancza).

SOFTWARE TECHNOLOGIES - BMEGEMIMW03

Contact hours: 2+0+1 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Tamás Péter, associate prof.

Comparison of traditional and component based programming technologies. Principles of object based programming. Component based technologies. Theoretical background and practical aspects of software modelling. The Internet as a resource. Programming in C#. Construction and elements of the .Net Framework. Net applications, ASP.NET applications. The ADO.Net. Distributed systems. Client serving applications.

Recommended literature:

1. Simon Robinson, Christian Nagel, Karli Watson, Jay Glynn, Morgan Skinner, Bill Evjen: Professional C#. 3rd Ed. Wiley. 2004. ISBN: 978-0-7645-5759-0

ARTIFICIAL NEURAL NETWORKS AND HYBRID SYSTEMS - BMEGEGTMW11

Contact hours: 1+1+0 **Credits:** 3 **Requirement:** examination

Responsible: Dr. Monostori László, professor

Symbolic and subsymbolic forms of knowledge representation and processing. Basics of pattern recognition, discriminant functions, preprocessing, feature extraction and selection, learning algorithms and their classifications, the Bayes decision algorithm. Concept of artificial networks, multilayer perceptrons, the back-propagation learning algorithm. Further models of ANNs and their applications. Handling of uncertainty, basics of fuzzyness, fuzzy control, fuzzy expert systems. Neuro-fuzzy approaches. Genetic algorithms.

Recommended literature:

1. Haykin, S., Neural networks, A comprehensive foundation, 2nd edition, Prentice Hall, 1999.
2. Lin and R., Neural Fuzzy Systems: A Neuro-Fuzzy Synergism to Intelligent Systems, Prentice Hall, 1996.
3. Horváth G., Neurális hálózatok és alkalmazásaik (Neural Networks and Applications), Műegyetemi Kiadó, Budapest, 1998.
4. Lecture Notes by the lecturer

ROBOT PROGRAMMING - BMEGEGTMW06

Contact hours: 1+0+2 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Mátyási Gyula, associate prof.

Hardware and software architectures of robot controller. Robot coordinate systems, robot kinematics, transformation between coordinate systems, interpolation modes, path planning. Robot programming methods, teach-in, numerical codes, high level program languages. Main structure of a robot language, commands, parameters, variables, input/output controlling, program organizing solutions. Programming of sensors and actuators of the robot.

Recommended literature:

1. J. Somló, B.Lantos, P.T. Cat : Advanced Robot Control Akadémiai Kiadó, 1997, ISBN 963-05-7350-4

SIMULATION OF CNC MACHINES AND ROBOTS - BMEGEGTMW12

Contact hours: 2+0+0 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr Erdős Gábor, research fellow

Overview of simulation programs. Mathematical principals (homogenious transformation matrices, graphs, Jacobi matrix). Modelling of mechanical systems (modelling of low level kinematical pairs, kinematical graphs). Modelling of machines with open kinematic chain (industrial robots). Solution of inverse kinematical problem (symbolically and numerically). Modelling of kinematical systems (calculation of velocity and acceleration functions). Simulation of traditional CNC machines. Structured reading and process of input files (lex/yascc type browsers). Calibration of simulation models (origos, setting of extremities). Usage of simulation (exercise of coincidence, problems of interpolation, choosing of solution branch, positioning of objects). Mechanical modelling based on graph structures (generating independent constrain functions). Simulation of parallel robots. Simulation of material selection.

Recommended literature:

1. Horváth, Markos: Gépgyártástechnológia (Machine Production Technology),Műegyetem Kiadó
2. LinkageDesigner User Guide
3. Edward, J. Haug, Computer Aided Kinematics and Dynamics of Mechanical Systems, Allyn and Bacon, 1989.

ASSEMBLY - BMEGEGTMW07

Contact hours: 1+1+1 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Szalay Tibor, associate prof.

Assembly (objects); definitions of assembly; units and items, object oriented assembly tree and documents;
Assembly (process); assembly procedures, operations, methods and organisation structures; process oriented assembly tree and documents;
Automation: Initiating, financial and social analysis of automation, specific and universal equipments, organizing and scheduling of the process;
Design for assembly
Quality control (object oriented view of quality assurance); probability functions and distributions, dimensional chains and analysis; calculation of resulting error and tolerance based on full and partial changeability;
Quality control (process oriented view): sensors and monitoring, control and statistical process control.

Recommended literature:

1. Boór Ferenc., Assembly (lecture note) http://www.manuf.bme.hu/
2. Lotter, Manufacturing Assembly Handbook, FESTO Blue Digest on Automation.

SPECIAL ROBOTS AND ROBOT APPLICATIONS - BMEGEGTMW08

Contact hours: 1+1+0 **Credits:** 3 **Requirement:** practical mark

Responsible: Dr. Arz Gusztáv, senior research fellow

Review of robot applications excluding the industrial robot applications. Personal, office, rehabilitation, surgery, house keeping, toy, construction, transport, agriculture, sea/deepwater, space, defence, civil protection robots. User and system requirements. Analysis of units and components. Design and simulation of a selected service robot application including a mobile unit, an arm unit, a gripper unit, as well as perception sensors.

Laboratory tests, control parameter setting on existing medical, civil protection, and cleaning robots.

Recommended literature:

1. S. Kalpakjian, S.R. Schmid, Manufacturing Engineering and Technology, Fourth edition, Prentice Hall, 2001, ISBN 0-201-36131-0
2. Y. Altintas, Manufacturing Automation, Cambridge University Press, 2000, ISBN 0- 521-65973-6

3. B. Benhabib, Manufacturing, Marcel Dekker Inc., 2003, ISBN 0-8247-4273-7
4. Assistenzroboter, FIPA Workshop F 112 Dez.2004 Stuttgart
5. Downloads recommended from: http://www.manuf.bme.hu/

MICROELECTRONICS IN CONTROL - BMEGEMIMW06

Contact hours: 1+1+0 **Credits:** 3 **Requirement:** practical mark
Responsible: Dr. Aradi Petra, associate prof.

Basics of control systems. Microelectronic devices in control engineering tasks. Building blocks, architecture and programming of microprocessor systems, development tools. Microcontrollers. Embedded systems. Programmable logic controllers (PLCs). Interfacing computers and other devices to real-world processes. RF and mobile devices. Mobile robotic applications.

Recommended literature:

1. Available at the ftp-site of the department: http://www.rit.bme.hu/ftp/pub/oktatas/

FINAL PROJECT IN ROBOTICS - BMEGEGTMWD2

Contact hours: 0+0+15 **Credits:** 19 **Requirement:** signature
Responsible: Dr. Mátyási Gyula, associate prof.

The aim of the subject of is to demonstrate the ability of the student to solve high level, practical engineering problems, based on acquired knowledge in the fields of mechanical engineering. The projects have to be prepared by the students under the guidance of supervisors. The Final Projects include tasks in design, simulations, laboratory tests, manufacturing as well as controlling, interfacing and software tasks. The expected result is mostly a Final Report prepared according to written formal requirements. During the Final Exam, the results have to be explained in an oral presentation.

Recommended literature: It depends on the topic of the project.

7.7. Subjects in Economics

MANAGEMENT - BMEGT20MW02

Contact hours: 3+0+0 **Credits:** 5 **Requirement:** practical mark
Responsible: Dr. Gyökér Irén, associate prof.

The objectives of the course are that the students know the duties of management and the attributes of the manager job with the current formed perception in different ages. Over the set targets the students will understand the characteristic of human behaviour, the behaviour of managers and their employee, the team properties in the labour-environment and the corporations how develop their functional rules. The applicable (for previous) management methods and their expected effects on the members of corporation and their capacities are presented in the course of the discussed themes.

Recommended literature:

1. Robert Vecchio, Organizational Behavior: Core Concepts, Dryden Press, 2005.
2. Debra L. Nelson and James Campbell Quick, Organizational Behavior: Foundations, Reality and Challenges, Thomson South-Western, 2005.
3. Donnelly, J.H., Gibson, J.L., Ivancevich, J.M., Fundamentals of Management, Irwin, USA, 1995.

MARKETING - BMEGT20MW01

Contact hours: 3+0+0 **Credits:** 5 **Requirement:** practical mark

Responsible: Dr. Szalkai Zsuzsanna, associate prof.

Marketing in the 21st century. Strategic marketing planning. The modern marketing information system. Consumer markets and buyer behavior. Business markets and business buyer behavior. Competitive strategies. Market segmentation, targeting, and positioning. Product strategy and new-product development. Managing services. Designing pricing strategies. Marketing channels. Integrated marketing communication.

Recommended literature:

1. Kotler, Ph., Armstrong, G., Saunders, J., V., Wong (2002): Principles of Marketing. Prentice Hall
2. Kotler, Ph. (2000): Marketing Management. Prentice Hall
3. Vágási M. (szerk.) (2007): Marketing-stratégia és menedzsment (Marketing Strategy and Management). Alinea Kiadó