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 2014/2015 academic year

Responsible for the Course:

Dr. Gábor Stépán

Professor, Member of the Hungarian Academy of Sciences

Compiled by:

Dr. András Szekrényes

Associate Professor

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The updated version can be downloaded from:

http://www.gpk.bme.hu/MSc/

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 [www.gvi.hu]. 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 30 credit points which are dedicated to the final project. This can be completed in two semesters (Final Project A and Final Project B). It is a prerequisite that at least 55 credit points as well as any "supplemental" subjects be completed prior to beginning the Final Project A. In order to begin the Final Project B, 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 "Industrial 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 Product Design	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		
	0/0/3/3/p			Teamwork project	0/0/3/3/p			
		0/13/0/15/p		Final Project A			0/13/15/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
			0/13/0/15/p	Final Project B				0/13/0/15/p
				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				
			1/0/1/3/p	Further Elective Subject			1/0/1/3/p	
		1/1/0/3/p		Further Elective Subject				1/1/0/3/p
				Criterion				
				Industrial Practice				
				Total				
30	29	32	29	Total credit points	29	30	29	32
17/4/1/22	14/4/5/23	8/14/3/25	6/14/2/22	Total contact hours	14/4/5/23	17/4/1/22	6/14/2/22	8/14/3/25
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 four 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		
	0/0/3/3/p			Teamwork Project	0/0/3/3/p			
		0/13/0/15/p		Final Project A			0/13/0/15/p	
				Special subjects / Major or Minor Elective Subjects				
		2/0/0/3/ p		Large-Eddy Simulation in Mechanical Engineering				2/0/0/3/p
		1/1/0/3/p		Open Source Computational Fluid Dynamics				1/1/0/3/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
			2/0/1/3/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	
			0/13/0/15/p	Final project B				0/13/0/15/p

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			
	0/0/3/3/p			Teamwork Project	0/0/3/3/p			
		0/13/0/15/p		Final Project A			0/13/0/15/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	
			0/13/0/15/p	Final project B				0/13/0/15/p

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			
2/1/0/5/p				Energy Conversation Units and their Equipment		2/1/0/5/p		
	0/0/3/3/p			Teamwork Project	0/0/3/3/p			
		0/13/0/15/p		Final Project A			0/13/0/15/p	
				Special subjects / Major or Minor Elective Subjects				
		1/0/3/4/p		Measurements in Thermal Engineering				1/0/3/4/p
		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	
			0/13/0/15/p	Final project B				0/13/0/15/p

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		
	0/0/3/3/p			Teamwork Project	0/0/3/3/p			
		0/13/0/15/p		Final Project A			0/13/0/15/p	
				Special subjects / Major or Minor Elective Subjects				
		1/0/2/4/e		CAD Technology				1/0/2/4/e
		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	
			0/13/0/15/p	Final project B				0/13/0/15/p

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. Péter Moson, Dr. György Paál, associate profs.

First order ordinary differential equations, difference between linear and nonlinear equations. Elementary methods of solution (undetermined coefficients, variation of parameters, etc.) 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. 2-dimensional autonomous systems. Linearization. Phase space analysis near equilibrium points (linearization, Poincaré theory), periodic orbits. 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. Emőke Lőrincz, 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. Gábor Stépán, professor

Review of Dynamics, Strength of Materials and Vibrations. D'Alambert's Priciple. Dynamic effects in Strength of Materials. Maximum equivalent stress calculation in structures of large acceleration (ventilator and turbine blades, engine parts). Natural frequencies and vibration modes of multi DoF systems. Rayleigh's ratio, Stodola iteration and Dunckerley's formula. Calculation of natural frequencies in beam structures by means of analytical estimation and finite element code. Natural frequencies and vibration modes of continuum beams (bending, longitudinal). Vibrations of strings. Calculation of natural frequencies in beam structures subjected to bending vibrations by solving partial differential equations. Bending vibrations of rotating shafts. Variation of natural frequencies due to gyroscopic effects. Campbell diagrams.

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. Gergely Kristóf, associate prof.

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. Transition. Turbulent boundary layers. BL control. Overview of computational fluid dynamics (CFD). Turbulence models. Fundaments of gas dynamics. Wave phenomena. Isentropic flow. Normal shock waves. Oblique shock waves, wave reflection. Prandtl-Meyer expansion. Supersonic jets. Atmospheric flows. Aerosols. Aeroacoustics. Pipe networks. Case studies.

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. Balázs Czél, assistant 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. Balázs Rakos, 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. Péter Korondi, 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. Gábor Körtélyesi, assistant prof.

The goal of the course is to give a theoretical overview on the fields of machine design and production technology, according to the detailed topics below. Some elements of the methodology is covered on the seminars throughout a semester project.

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. Gergely Kristóf, 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: Numerical approximations of derivatives and integrals. Discretisation of divergence, gradient and Laplace operator by means of finite volume method.Numerical modelling of incompressible flows, resolution of pressure-velocity coupling in terms of psi-omega method and pressure correction method.Characteristics of turbulence and turbulence modelling.Application of finite volume discretisation method in a one-dimensional case.Stability of the central differencing scheme, upwinding, and numerical diffusion.Solution of algebraic systems which are obtained by the discretisation of the governing equations of fluid flows.Iterative methods, multigrid methods.Compressible flow modelling.Method of characteristics, application of finite volume method.Introduction to multiphase flow modelling.Application of User Defined Functions (UDFs) in ANYSYS-Fluent simulation system.Seminars in CFD Laboratory: Generation of block-structured meshes with ICEM CFD software.Individual assignment.Convergence checking, mesh independency checking, comparison of results of various models with measured data.Handing in the report of the individual assignment.Group assignment (in groups of 3 students).Convergence checking, mesh independency checking, comparison of results of various models with measured data.Tutorial examples in multiphase flow modelling.Handing in the report of group assignment.UDF examples.Presentation of the results of group assignments.

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. János Vad, 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

TEAMWORK PROJECT - BMEGEÁTMWTP

Contact hours: 0+0+3 **Credits:** 3 **Requirement:** practical mark
Responsible: Dr. Viktor Szente, assistant prof.

Experimental and/or numerical (CFD) teamwork project proposals will be announced by the supervisors on the registration week or before for group of 2-3 students. The Teamwork Project proposals are defined as being complex problems for the 1st or 2nd semester, and also can be continued partly by a single student in course of the Final Project A or B (BMEGEÁTMWDA or BMEGEÁTMWDB) in the 3rd and 4th semester, hence resulting in a fully complex MSc Thesis of the student at the end of the curriculum. A so-called Evaluation Team (ET) is formed in that the group's supervisor + two advisors are participating, being the members of ET.*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/BMEGEATMWTP

FINAL PROJECT A - BMEGEÁTMWDA

Contact hours: 0+13+0 **Credits:** 15 **Requirement:** practical mark
Responsible: Dr. György Paál, associate 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) project proposals are announced by the supervisors well before the registration week. The 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 B (BMEGEÁTMWDB) 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 Final Project A and further on the Final Project B 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 Final Project A proposals are announced also by the Dept. Hydrodynamic Systems (under their own subject code BMEGEVGMWDA).

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/BMEGEATMWDA

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. Gergely Kristóf, 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

OPEN SOURCE COMPUTATIONAL FLUID DYNAMICS – BMEGEÁTMW11

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

Responsible: Dr. Gergely Kristóf, associate prof.

Introduction to OpenFOAM including Linux basis, and other required software such as gnuplot and paraview. Installation of OpenFOAM on several Linux distributions and virtual linux systems (Ubuntu, Opensuse, Fedora) from packages and on other systems from source. Solution of simple 2D fluid dynamics problems using OpenFOAM (driven cavity flow, 2D boundary layer, Poiseuille flow) including the comparison with theoretical results. Detailed introduction to OpenFOAM software components including meshing tools, solvers and post-processing tools. Single phase stationary and transient flows, turbulence, compressible flows. Introduction to models, boundary conditions and solvers required for the simulation of these problems. Examples on these problems. Multiphase and reactive flows, including the introduction to models, boundary conditions and solvers required for the simulation of these problems. Examples on these problems. Extension of OpenFOAM capabilities by program code development in C++. Compiling code components, the implementation of boundary conditions, applications and models. Personalized projects using OpenFOAM. Further open source CFD tools (Code Saturn, Palabos).

Recommended literature:

1. http://www.ara.bme.hu/~hernadi/OpenFOAM/
2. Weller HG, Jasak H and Tabor G. A tensorial approach to computational continuum mechanics using object-oriented techniques. Comput Phys 1998; 12: 620–631.
3. Jasak H. OpenFOAM: Open source CFD in research and industry. Int J Naval Archit Ocean Eng 2009; 1:89–94.
4. http://elte.prompt.hu/sites/default/files/tananyagok/numerikus_prognosztika/ch04.html

MULTIPHASE AND REACTIVE FLOW MODELLING – BMEGEÁTMW17

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

Responsible: Dr. Jenő Miklós Suda, assistant prof.

Physical phenomena, major concepts, definitions and modelling strategies. Mass transport in multi-component systems: diffusion and chemical reactions. Modelling chemical reactions: flames, combustion models, atmospheric reactions. Fluid dynamical and thermal phenomena in two-phase pipe flows: flow regimes in vertical, horizontal and inclined pipes. Advanced multi-phase flow instrumentation. Transport through deforming fluid interfaces: jump conditions at discontinuities. Single-fluid and interpenetrating media modelling approaches. Obtaining practical transport equations for multiphase pipe flows by cross sectional integration and cross sectional averaging. Closure relations. Mixture and multi-fluid models. Using experimental correlations. Relevant dimensionless numbers. Gravity and capillary waves. Dispersed particle transport. Sedimentation and fall-out, particle agglomeration and break-up. Bubble growth and collapse. Phase change and heat transfer in single-component systems: boiling, cavitation, condensation. Related heat transport problems and industrial applications. Computational Multi-Fluid Mechanics (CMFD): general methods and limitations, usage of general purpose computational fluid dynamics codes, design of specialized target software. Numerical modelling free surfaces and fluid-fluid interfaces. Review of 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. Csaba Hős, assistant prof.

Overview of the program, introduction. Overview of applied numerical methods (Newton-Raphson, Runge-Kutta). 1D instationary flow of quasy-constant density fluid, MOC. Method of characteristics (realisation). Dynamics of air wessel. Dynamical model of pumps. Water hammer, transient pipe network simulation, homework. Open channel flow, basic equations. Lax-Wendroff scheme. Application of MOC for open channel flow. Gasdynamics. 1D transient gas.

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

BUILDING AERODYNAMICS - BMEGEÁTMW08

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

Responsible: Dr. Jenő Miklós Suda, assistant prof.

Basics of meteorology: characteristics of atmospheric boundary layer and its modelling. Arising of wind forces, bluff-body aerodynamics: boundary layer separation, characteristics of separated

flows, vortices, their effects on the flow description of complex 3-dimensional flow fields. Wind comfort, dispersion of pollutants in urban environment / Numerical simulation of dispersion of

pollutants in urban environment by using MISKAM code. Numerical simulation of dispersion of pollutants in urban environment using the MISKAM code. Usage of wind tunnels in determination of wind loading. Flow visualization around buildings in wind tunnel. Static wind load on buildings and structures, prediction of static wind load by using EUROCODE and ASCE standards. Fundamentals and philosophy. Wind and structure interaction, aero-elasticity. Aerodynamics of bridges, prediction of dynamic wind load on buildings, structures by using EUROCODE, basics of numerical simulation using solid-fluid interaction. Design of cooling towers. Design and wind load of water spheres. Wind load on telecommunication masts - aerodynamic and related design issues, developments. Aerodynamics of membrane structures. CFD and wind tunnel case studies (large buildings, stadium roofs).

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. Jenő Miklós Suda, assistant prof.

Introduction, bluff body aerodynamics. Characteristics of atmospheric boundary layer. Basics of car design (in co-operation with MOME: Moholy-Nagy University of Arts and Design Budapest). Aerodynamics of automobiles. Aerodynamics of buses and trucks. Aerodynamics of racing cars. Wind tunnels and their use for vehicle aerodynamics. Definition of projects, forming groups of students.

Measurement of car models evaluation of car bodies from aerodynamic and design point of view (in co-operation with MOME: Moholy-Nagy University of Arts and Design Budapest).
Individual project: passenger car modelling. 2-4 students form one group. Every group will receive two modelling wood of 3 various given dimensions. With the help of plasticine, a passenger car of M 1:20 scale can be created. The relative position of the pieces of woods can be freely chosen, as far as the model resembles a car. The ground clearance (underbody gap) is 11mm, the distance of the axes is 140mm. The diameter of the wheels is 30mm, their width is 8mm. Wheels can be formed of the plasticine provided. In the larger piece of wood – under the passenger compartment – four boreholes are created, in order to attach the model to the aerodynamic force measuring mechanism. The maximum length of the model is 250mm, its minimum height is 60mm, and its width is between 82 and 90mm. The perpendicular cross section of the model has to be determined (together with the wheels), in order to determine drag and lift coefficients. There is a possibility to place attachments on the car model, like spoilers, ski boxes, etc. Besides the force measurement, there will be a possibility for flow visualization around the car, during which the location and size of the separation bubbles, the size of the dead water region behind the car, effect of spoilers and other attachments, and soiling of the rear face of the car can be observed. The measurements groups have to prepare a project presentation on the last class. The groups have to send their presentation by e-mail 2 working days before the presentation at the latest.

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. János Vad, associate prof.

3D homogeneous wave equation and the general solution. The 3D solution of the wave equation in bounded space, room modes. The sound propagation in tubes, the sudden cross-sectional area change and tube termination. The simple expansion chamber silencer, and the sound propagation in horns. Sound propagation in duct and higher order modes. The ray theory, sound propagation in non-homogeneous media. Spherical waves, and the point monopole, dipole and quadrupole sound sources, model laws. The flow generated sound, Lighthill's acoustic analogy and the inhomogeneous wave equation. The attenuation of sound waves. Acoustic measurements, microphones, analysers, calibrators. Anechoic and reverberating chambers. Basic acoustic measurement problems. The sound intensity measurement, the microphone array.
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. György Paál, associate professor

Introduction to physiology. Circulation system, arterial and venous system. Blood flow measurement methods, invasive techniques. Non-invasive blood flow measurements, Transmission properties of cuff-systems, estimation of eigenfrequency. Introduction to the method of characteristics (MOC). MOC and Solution for rapid change, Alievi (Joukowsky)-wave. MOC and study of the transmission properties of invasive blood pressure measurement technique (arterial catheter). Models and methods for the description of blood flow in blood vessels, material properties, Streeter-Wiley Model 1 and Model 2. Characteristic physiological quantities and their influence in hemodynamics. Flow in aneurysms.

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. György Paál, 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 shear layers, jets, boundary layers. Compound matrix method.

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. György Paál, associate professor

Wave equation. Lighthill's theory, monopole, dipole, quadrupole sound sources. Green's functions on the example of the vibrating string. Free space Green's functions. Modification of Green's functions in the vicinity of solid bodies. Vortex sound equation.

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 B - BMEGEÁTMWDB

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

Responsible: Dr. György Paál, associate 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 Final Project A (BMEGEÁTMWDA). The Final Projects A and B together serves as a two-semester project that results in the Master (MSc) Thesis of the student. In course of the Final Project B 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 Final Project A that was announced by the Dept. Hydrodynamic Systems (under subject code BMEGEVGMWDA) must continue their project in course of the Final Project B announced also by the Dept. Hydrodynamic Systems (under code BMEGEVGMWDB).

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/BMEGEATMWDB

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. András Szekrényes, associate prof.

The basic equations of linear elasticity, Green-Lagrange strain tensor. Stability of linear elastic systems, the Euler method. FE formulation of stability problems, geometric stiffness matrix. Buckling, lateral buckling and lateral-torsional buckling of slender beams with symmetric cross section. Torsion of straight prismatic beams. Second order dynamics, vibration of beams with initial load. Dynamic stability analysis including flutter and divergence. Elastic structures subjected to conservative and nonconservative loads. Beck's column, stability diagrams and phase plane portraits. FE solution of nonlinear dynamic problems. Direct time integration schemes, central difference method, Newmark's method, numerical examples. Modeling of parametrically excited linear elastic systems, harmonic balance method. Solution for system of Mathieu-Hill DE equations, application of infinite matrices and finite determinants. Elastic column subjected to periodic compressive force, stability diagrams, calculation of the displacement response. Simulations and animations of parametrically unstable systems. Classification and FE solution of nonlinear static structural problems, classical and modified Newton-Raphson methods. Tangent stiffness matrix and iteration schemes. The principle of virtual work. Degenerate beam element with von Kármán type nonlinearity. Nonlinear TRUSS structures. Nonlinear vibration of elastic structures, solution by direct iteration technique. Chaotic motion of elastic structures. Nonlinear bending of elastic beams including large displacements and large strains. Modeling examples in ANSYS including elasticity, plasticity, static and dynamic elastic stability, nonlinear structural static/dynamic and thermomechanical 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. Attila Kossa, associate prof.

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.

TEAMWORK PROJECT - BMEGEMMMWPA

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

Responsible: Dr. András Szekrényes, associate prof.

Solution of complex problems by forming group of students including the following topics: cutting processes, vibration measurements, robot control, stability theory.

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

FINAL PROJECT A - BMEGEMMMWDA

Contact hours: 0+13+0 **Credits:** 15 **Requirement:** practical mark

Responsible: Dr. András Szekrényes, associate prof.

The Final Project A 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. Attila Kossa, assistant professor

Introduction to the constitutive modelling in solid mechanics. Classification of the constitutive theories. Gradient, divergence and curl in cylindrical coordinate system. Small strain theory. Compatibility of strain. Governing equations of linear elasticity. Hooke's law. Plane stress and plane strain problems. Airy stress function.Torsion of prismatic bar.Analytical stress solution of rotating disc and of thick-walled tube with internal pressure.One-dimensional plasticity. Uniaxial extension and compression problems with hardening. Elastic-plastic deformation of thick-walled tube with internal pressure. Haigh-Westergaard stress space. Formulation of the yield criteria. Linear isotropic and kinematic hardening. Nonlinear hardenings. Formulation of the constitutive equation in 3D elastoplasticity. Radial return method.

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. Gábor Stépán, professor

Nonlinearities in mechanical systems: springs, dampers, inertia. Phase plane analysis of 1 degree-of-freedom systems. Saddles, nodes and spirals, stable and unstable equilibria. Vibrations of conservative nonlinear systems. Catastrophe theory: typical bifurcations of equilibria. Construction of trajectories and their analysis in case of inverted pendulum supported by spring, pitchfork bifurcation. The dynamic effects of nonlinear damping. Forced vibration and resonances in systems of nonlinear springs. Analytical and numerical calculation of resonance curves in case of hardening and softening characteristics. Self-excited vibrations. Liénard and Bendixson criteria for limit cycles. Hopf bifurcation theory. Stick-slip oscillations, estimation of stable and unstable periodic motions.

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. Ádám Kovács, associate prof.

Coupled field problems. Diffusion equations. Coupled piezo-thermo-mechanical equations. Steady-state thermal analysis. Thermo-mechanical analysis. Micro-electromechanical systems. Beam and plate type microstructures. Sensors and actuators. Piezoelectric-thermo-mechanical analysis of an actuator. Electro-mechanical analysis of a capactive pressure sensor. Fluid-structure interaction. Fluid-structure coupled acoustic analysis. Contact problems. Contact simulation of two microcantilevers. Shape memory alloys, smart structures.

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. Ambrus Zelei, research associate

Overview of structural elements and kinematic fundamentals. Basics of synthesis of planar mechanisms. Fourbar mechanisms. Coupler curves. Single and double dwell mechanisms. Velocity and acceleration analysis. Apparent velocity, Aronhold-Kennedy theorem, coordinate partitioning method, and the method of appended driving constraints. Spatial representation of position and orientation. Parameterization of rotations, Euler angles, Tait-Briant angles, Roll-Pitch-Yaw angles, Axis-angle representation, Exponential mapping, Euler parameters. Joint- and operational space. Forward kinematics. The Denavit-Hartenberg convention. Equation of motion of robots, Euler-Lagrange method, Recursive Newton-Euler approach. The concept of natural coordinates. Dynamic equation of motion in terms of non-minimum set of generalized coordinates. Constrained systems. Service robot-, and haptic application examples. Impulsive dynamic analysis. Numerical simulation.

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. András Szekrényes, associate prof.

General theory of free torsion of prismatic bars. Saint-Venant warping function, the circulation theorem of shear stresses. 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 equation 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. Nonlinear bending theory of slender beams by E.P. Popov. Nonlinear DE of flexure. Solution by elliptic integrals of the first and second kind. Solution of classical beam problems including large deformations. FE formulation of Timoshenko beams. Isoparametric Timoshenko beam element, shear locking, interpolation with exact nodal solution, examples. 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. András Szekrényes, associate prof.

Strain measurement methods, theory and practice, strain gauges. Application to an aluminium block. Linear elastic fracture mechanics of composites, fracture model of Griffith, definition of critical energy release rate. Evaluation of fracture mechanical test results. Direct and indirect data reduction schemes. Standard and direct beam theories, J-integral, the virtual crack-closure technique, compliance calibration, area method. Classification of fracture tests, mode-I and mode-II configurations. Manufacturing of composite specimens. Force and displacement control in fracture mechanics. Necessary and sufficient conditions of stable crack propagation in brittle materials. Stability criterion in theory and practice. Demonstration examples for stable and unstable crack advance. Test methods for the mode-III interlaminar fracture, the modified split cantilver beam, edge-cracked torsion and 4-point plate bending specimens. Dynamic stability and vibration analysis of delaminated beams. Vibration testing using modal hammer and sweep excitation tests. Measurement of the frequency response function and mode shapes. Evaluation of vibration tests. Numerical simulation of parametric instability in delaminated beams by harmonic balance and finite element methods. Mode shape simulation and calculation of phase plane portraits. The mixed-mode bending problem. Mode partitioning in mixed-mode I/II tests by global and local methods using distributed dislocation theory. Application of improved beam theory schemes (Winkler, Timoshenko) to cracked beams. Fracture envelopes and fracture criteria of laminated materials.

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 B - BMEGEMMMWDB

Contact hours: 0+13+0 **Credits:** 15 **Requirement:** signature

Responsible: Dr. András Szekrényes, associate prof.

The Final Project B subject is dedicated to prepare the second half of the MSc thesis. As the continuation of the Final Project Project A, 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 Final Project A, 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. Ferenc Lezsovits, associate professor

Course is started with introduction of fuel properties and fuel supply systems. It is followed by calculation of mass and energy balance of combustion, stoichiometry and CO2 and pollutant emission, flue gas loss calculation, condensation of flue gas components. Heat transfer in combustion chamber has important role on energy balance and retention time formation. After that combustion process of different fuels, parameters of combustion will be presented as homogenous / heterogeneous reactions, flow type and concentration effects on chemical reactions. Nowadays application of catalysts in combustion process and flue gas cleaning has become important part of this technology. Anaerobe biogas generation, gas cleaning and features and gasification technology overview, features of generated gas, gas cleaning technologies, tar filtering and/or condensation, torrefaction and pirolysis will be discussed as well. Carbon capture and storage (CCS) technologies will be also presented. Int he end comparison of different thermal conversion technologies (combustion, gasification, etc.) on mass and energy balance will be presented.Finally solutions applied in firing technic will be demonstrated as firing system in general, control and regulation, firing system principals for liquid and gaseous fuels, andfor soild fuels, and waste material incineration.

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.

ENERGY CONVERSATION UNITS AND THEIR EQUIPMENT - BMEGEENMWEP

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

Responsible: Dr. Ákos Bereczky, associate professor

Basics. Cooling systems and main parameters. Absorption cooling systems and special cooling systems. Fuel cells. Combustion technology, parameters and emissions. Different hot water and steam generation systems. Different hot water and steam generation main parameters. Steam turbines, different steam turbine cycles. Steam turbines, different steam turbine constructions. Gas turbines, different gas turbine constructions and cycles. Main parameters and characteristic of internal combustion engines. Management of internal combustion engines. Gas engines. Cogeneration and tri-generation systems and parameters.

Recommended literature:

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

TEAMWORK PROJECT - BMEGEENMWPR

Contact hours: 0+0+3 **Credits:** 3 **Requirement:** practical mark
Responsible: Dr. Tamás Laza, assistant prof.

The complex task covers a semester project in the diverse topics of energetics.
Recommended literature: It depends on the topic of the project.

FINAL PROJECT A - BMEGEENMWDA

Contact hours: 0+13+0 **Credits:** 15 **Requirement:** practical mark
Responsible: Dr. Ákos Bereczky, associate prof.

In course of the Final Project A 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

MEASUREMENTS IN THERMAL ENGINEERING - BMEGEENMWM2

Contact hours: 1+0+3 **Credits:** 4 **Requirement:** practical mark
Responsible: Dr. Ákos Bereczky, 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.

SIMULATION OF ENERGY ENGINEERING SYSTEMS - BMEGEENMWSE

Contact hours: 1+0+2 **Credits:** 3 **Requirement:** practical mark
Responsible: Dr. Pál Szentannai, associate 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. Balázs Czél, assistant prof.

Physical backgrounds, mechanism and models of heat conduction in solids; measurement of thermo-physical properties; steady state and transient methods; numerical modeling of 1D and 2D heat conduction problems, inverse heat conduction problem. Heat conduction review (heat diffusion equation, boundary conditions). What are thermophysical properties? Different heat conduction models. Finite difference and control volume method for the solution of heat conduction problems. Measurement of the thermal conductivity. Measurement of the thermal diffusivity. Measurement of the specific heat capacity; direct determination of the temperature dependency of the properties. Inverse heat conduction problems. 2D steady-state heat conduction with contact boundary condition. Transient heat conduction with different boundary conditions (modeling the laser flash method). Transient heat conduction with contact boundary condition. Transient heat conduction with temperature dependent thermophysical properties (modeling the BICOND method).

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. Ádám Kovács, 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. Krisztián Sztankó, assistant professor

Preliminary, property of Parsons and Laval steam turbines, property of modern steam turbines. Properties of impulse stage. Curtis stage, negative reaction number evoluation, sonic speed, velocity bended, efficiency curve, properties of reaction stage, long blade bended criteria, equistress design, determination of steam turbine’s main geometry, wet steam turbines, calculate pressure variation with Stodola constans. Reheated condensation steam turbine. Design of Package gas turbine. Uncool gas turbine cycle calculation. Real gas turbine cycle and optimum parameters. Properties of single shaft and dual shaft gasturbine, wing shape theory and compressor stage.

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

FINAL PROJECT B - BMEGEENMWDB

Contact hours: 0+13+0 **Credits:** 15 **Requirement:** signature

Responsible: Dr. Ferenc Lezsovits, 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. Károly Váradi, 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. Márton Takács, associate prof.

Introduction to Advanced Manufacturing. Visiting the manufacturing laboratory of the Department. Conventional machining operations. Fundamentals of machining operations. Mechanics of metal cutting. Machinability. Chip control. Fundamentals of advanced manufacturing (non-conventional machining). Reverse engineering. Rapid Prototyping. Mold design and manufacturing. Production Planning - Material Requirements Planning. Production Planning - Advanced models and algorithms. Consultation on semester essay. Electro Discharge Machining EDM), processes and application. Micro EDM machining. Laser Beam Machining. Laser marking. Rapid Prototyping. NC tool path planning by CAM system. Hard

Cutting. Gear production.

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

TEAMWORK PROJECT – BMEGEGEMWP1

Contact hours: 0+0+3 **Credits:** 15 **Requirement:** practical mark

Responsible: Dr. Tibor Szalay, associate prof.

The complex task covers a semester project in the diverse topics of manufacturing.

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

FINAL PROJECT A - BMEGEGEMWDA

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

Responsible: Dr. Tibor Szalay, associate prof.

In course of the Final Project A 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:** examination

Responsible: Dr. Attila Piros, assistant prof.

Lecture topics: Introduction, using of the intelliFiles. Theory of the TOP-DOWN design. Integrated CAD systems. Virtual product development. Parametric design. Design of the mechanisms. Topics of the labs: Introduction, overview on the 3D part modelling. TOP-DOWN design in static constructions. Overview on 3D assembly modelling. Design of the cast parts. 3D model based technical drafting.Integration of the imported 3D data. Modelling of the parts with similar geometry. Design of the moving parts' kinematic. Modelling of the complex kinematic. Creating of kinematic analyses. TOP-DOWN design in moving constructions. Tolerancing in the CAD systems.

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. István Mészáros, 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. Tibor Goda, 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. Gyula Mátyási, associate prof.

Introduction; demands and requirements of absolving mark in the subject; principles, concepts, terms, definitions concerning on manufacturing process planning and manufacturing processes, equipment, tooling and experience; The stages and steps of manufacturing process planning; deterministic and heuristic methods, issue of Type and Group Technology, methods of prevention and elimination; Production analysis; general sequencing problems; determination of all sequence variations; methods of matrix reduction and vector variants; abstract methods for process plans and production workflows; Scheduling; Process chains and diagrams; shop-floor programming and scheduling (GANTT diagrams), Network plans, leak control (Process graphs and trees), process chain representations, diagrams (Workflow techniques). Assembly (objects); definitions of assembly; units and items, object oriented assembly tree and documents Assembly and manufacturing (processes); assembly procedures, operations, methods and organisation structures; process oriented assembly tree and documents. Quality control (object and process oriented view of quality assurance); probability functions and distributions, dimensional chains and analysis; assembling methods and assurance; economic view of manufacturing; Quality assurance; Production strategies (TQC, JIT); statistical process control (SPC); measure and charts of process capability; charts attributes..

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. István Németh, associate professor

The lectures include the following topics: Fundamentals of the kinematics of machine tools and the NC technology. Classification of metal-cutting machine tools. Selection criteria of machine tools. Structural building blocks: friction, rolling and hydrostatic guideways; ball screws; linear motors; rack and pinion mechanisms; hydrostatic screws; indexing and NC rotary tables; rotary actuators: gears, warm wheel, torque motor. Spindles: belt drive, gear drive, direct drive, integrated spindle; rolling, hydrostatic, aerostatic bearings; tool holders and tool clamping; lathe and milling spindles. Lathes and turning centres. Milling machines and machining centres. Automatic tool and worcriece changing peripheries. Multi-functional machine tools. Parallel kinematics machine tools.The seminars support the design assignment and help the student in selecting the motion unit components (i.e. ball screw, rolling guideway, servo motor) and designing the main structural element i.e. frames, moving slides, tool changers) 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. Jenő Lovas, assistant 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 B - BMEGEGEMWDB

Contact hours: 0+13+0 **Credits:** 15 **Requirement:** signature

Responsible: Dr. Tibor Szalay, 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.

7.6. Subjects in Economics

MANAGEMENT - BMEGT20MW02

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

Responsible: Dr. Irén Gyökér, 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. Zsuzsanna Szalkai, 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

7.7. Further Elective Subject

BIOLOGICALLY INSPIRED SYSTEMS - BMEGEMIMGBI

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

Responsible: Dr. Péter Korondi, professor

The design of engineering structures increasingly involves mimicking and improvement of natural, living structures to perfection. In addition to a more accurate understanding and systematization of living systems, it is increasingly important that both engineering students and engineers get acquainted with this topic. The basic goal of the course is the analysis of different biological systems and of the engineering structures mimicking them throughengineering and systems theory considerations. Specific solutions of biological systems for different materials, structures, sensor systems, motion and control can be properly applied.

Recommended literature:

1. Jenkins C. Bio-Inspired Engineering. Momentum Press. 2012
2. Nachtigall W. Bionik - Grundlagen und Beispiele für Ingenieure und Naturwissenschaftler, Springer. 2002
3. Biomimetics - Biologically Inspired Technologies, CRC Press, 2006
4. Petra Gruber, Dietmar Bruckner, Christian Hellmich, Heinz-Bodo Schmiedemayer, Herbert Stachelberger, Ille C Gebeshuber (eds). Biomimetics – Materials, Structures and Processes. Examples, Ideas and case Studies. Springer, 2011

7.8. Criterion

INDUSTRIAL PRACTICE - BMEGEMMMWSZ

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

Responsible: Dr. András Szekrényes, associate prof.

One of the requirements to obtain the M.Sc. diploma is to carry out the internship in a company that performs some activities in the field of mechanical engineering. The industrial practice fulfilled in the BSc level is accepted automatically if the student accomplished the internship through the organization of the Department of Applied Mechanics. If the accomplishment took place through the organization of another department, then a certification needs to be provided to the department's responsible (Dr. András Szekrényes). If the student does not possess a valid industrial practice, then it has to be accomplished in the course of the MSc qualification. The required duration of the industrial practice is 4 weeks. It is possible to request the organization of the industrial practice from the department's responsible. To obtain the signature in Neptun it is required to apply the Industrial practice subject before the acqusition of the M.Sc. diploma.