UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie

School of Engineering

Department of Mechanical and Aeronautical Engineering

Fluid Mechanics MTV310
Metallurgical Fluid Mechanics NTV310

Prepared by: Prof Ken Craig
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ORGANISATIONAL COMPONENT

1. USING THE STUDY GUIDE

This document consists of three parts. In the first part, introductory and organisational information are given, for example who the lecturer is, what to expect from the lecturer and what is expected from you. The second part contains very important study component information and the third part is the laboratory and experimental guides.

2. DEPARTMENTAL STUDY GUIDE

This study guide is a crucial part of the general study guide of the Department. In the study guide of the Department , information is given on the mission and vision of the department , general administration and regulations (professionalism and integrity, course related information and formal communication, workshop use and safety, plagiarism, class representative duties, sick test and sick exam guidelines, vacation work, appeal process and adjustment of marks, university regulations, frequently asked questions), ECSA outcomes and ECSA Graduate Attributes, ECSA knowledge areas, CDIO, new curriculum and assessment of cognitive levels. It is expected that you are very familiar with the content of the Departmental Study Guide. It is available in English and Afrikaans on the Department's website.

English:

https://www.up.ac.za/media/shared/120/Noticeboard/2020/departmental-studyguide-eng-2020_version21jan2020-002.zp185016.pdf

Afr:

https://www.up.ac.za/media/shared/120/Noticeboard/2020/departementele-studiegids-afr-2020_weergawe21-jan2020-002.zp185015.pdf

Take note of the specific instructions in the above study guide on:

a. **Safety**
b. **Plagiarism**
c. **What to do if you were sick (very important)?**
d. **Appeal process on the adjustment of marks**

3. GENERAL PREMISE AND EDUCATIONAL APPROACH

The aim of the module *Fluid Mechanics MTV310/ Metallurgical Fluid Mechanics NTV310* is to provide the student with the basic principles of fluid mechanics and conduction heat transfer and their application in a variety of practical engineering problems. After successful completion of the course, the student will be able to solve such problems independently. The general aim with this module is to emphasise **understanding** rather than memorising, in order to stimulate **creative thinking** and the development of **innovative skills** amongst students in the area of fluid mechanics and introductory heat transfer.

Fluid mechanics is a science that describes the mechanics and dynamics of fluids (liquids and gases) and is based on the conservation laws of mass, momentum and energy. These three laws are continuously cast in the most applicable and simplest form to describe the problem at hand. The application field of fluid mechanics covers a wide range of disciplines that include aircraft and vehicle propulsion, stability and buoyancy of ships and submarines, numerical simulation of fluid flow, experimental model tests, drag on passenger cars, aircraft and projectiles, and channel flow, to name but a few.

The course module is one of the cornerstones of the Thermofluids curriculum in the Mechanical Engineering degree together with modules such as Thermodynamics, Aerodynamics, Fluid and Thermal machines, and Heat Transfer.

A problem-driven approach to learning is followed. Student-centred and co-operative learning and teaching methods are applied during lectures in order to optimally develop the above skills, as well as to stimulate the development of communication skills, interpersonal skills and group dynamics. It is expected that you would participate in discussions during lectures, as your fellow students are dependent on your inputs.

Refer to the Departmental Study Guide for the outcomes of this Module in the ECSA framework.

4. LECTURERS, VENUES AND CONSULTING HOURS

	Name	**Room No. and Building**	**Telephone No. and E-mail Address**
Lecturers			
	Prof Ken Craig	Eng III 6-86	420-3515 (W)
	(and course coordinator)		083-310-8946 (cell)
			ken.craig@up.ac.za
	Dr Lelanie Smith	Eng I 9-13	lelanie.smith@up.ac.za
Teaching assistants	TBA		

Location of the Laboratory for practicals:
Wind tunnel Lab

Consulting hours:
Refer to schedule outside office door.
<u>Ken Craig:</u> 5 lecture periods are reserved for consultation during lecture weeks. Additional appointments can be made per email as indicated.

Mailbox:
All practical reports must be handed to the relevant teaching assistant in his/her office. See Appendix A for the allowed time of report writing and penalties for late submission.

5. WHAT TO EXPECT OF THE LECTURERS

The lecturers undertake to:

a. share with you their knowledge and experience and, in doing so, prepare you for practice;

b. attempt to establish a passion for the subject within you and aid your academic development;

c. hand out test results as soon as possible;

d. be well-prepared for formal lectures;

e. do everything in their ability to explain the work to you as well as possible and to make it as understandable as possible;

f. treat you in a professional manner;

g. be fair and courteous towards you at all times;

h. never humiliate you for asking a question during lectures (even if you and/or your class-mates should regard it as a 'stupid' question);

i. do everything in their power to help you pass the course.

6. WHAT WE EXPECT OF YOU AS STUDENT

We expect you to:

a. show loyalty and integrity;

b. be diligent and enthusiastic in your work;

c. behave in a disciplined manner in class;

d. discuss any problems you may experience with regard to the subject with me as soon as possible (please refer to the consultation times section)

e. ask questions freely during lectures;

f. act professionally.

7. STUDY MATERIALS

Prescribed text book:
Frank M White, Fluid Mechanics, Eight Edition, McGraw-Hill.

There are many other text books for this classical field of engineering that contain essentially the same information. The internet also has many sources for fluid mechanics.

Class notes:
Class notes of a fill-in type will be provided electronically to students in PDF format. These will correspond to the Powerpoint slides used in class. At the completion of each section, complete slides will be made available in PDF format.

Study guide:
This study guide has been compiled with care to help you work independently and to provide a structured learning environment. The document may be modified by means of a notice in class or on ClickUP.

8. LEARNING ACTIVITIES

Lectures:
MTV310:
3 lectures per week for 12 weeks. It is expected from you to spend a total of 160 hours on this module (16 credits). In addition, it is expected that you attend class regularly and cooperate in class discussions.
NTV310:
3 lectures per week for about 7 weeks. It is expected from you to spend a total of 80 hours on this module (8 credits). In addition, it is expected that you attend class regularly and cooperate in class discussions.

Group work:
Modern engineering education places a lot of emphasis on the ability of student to operate in groups. For this module you will be divided into groups of 5 or 6. **This allocation will be done automatically, to mimic the engineering project environment where you will *not* have a choice with whom you work**. These groups will cooperate during practicals. For all group work only one consolidated report is handed in. To prevent certain members not participating, each student will perform an individual evaluation of each other's contribution (see Appendix A).

Assignments and problems:
The regular working through of problems and assignments as announced in class is of critical importance in the mastering of the module. It is therefore expected that you do these problems regularly. These problems will not be handed in, but will be tested regularly in class tests.

Practicals
MTV310:
There are 3 compulsory practicals:
1. Aerodynamics wind tunnel experiment
2. Fluid friction experiment
3. Computational Fluid Dynamics practical (MTV310)

NTV310:
There are 2 compulsory practicals:
Choose one of the following:
1. Aerodynamics wind tunnel experiment
2. Fluid friction experiment

This practical will be on a Metallurgical application:

3. Computational Fluid Dynamics practical (NTV310)

See Appendix A for regulations regarding practicals. Remember that **closed shoes** must be worn for practicals in the Labs.
The scheduling of practicals will be done through ClickUP.

Demonstrations:
During class demonstrations will be given to emphasise and illustrate the study material. These will take the form of animations.

Tests and exams:
All **class** tests will be **open book** in an attempt to simulate the engineering environment with the availability of reference material. The **semester tests and exams** will however be **closed book**, but students will be allowed to bring in 1x A4 paper with writing of their choice on both sides (2x A4 for exams). Additionally, a formula sheet will be provided in the question papers to remove the emphasis from memorisation and repeating of facts.

The standard practice of the Mechanical Engineering department is followed when students are absent from tests and exams. Refer to Departmental Study Guide.

9. RULES OF ASSESSMENT

MTV310:
Semester marks are calculated as follows:

Test 1	35%
Test 2	35%
3 Practicals and 5 class tests	30%

NTV310:
Semester marks are calculated as follows:

Test 1	70%
2 Practicals and 3 class tests	30%

MTV310/NTV310:
The final mark is calculated as follows:

Semester mark:	50%
Exam mark:	50%

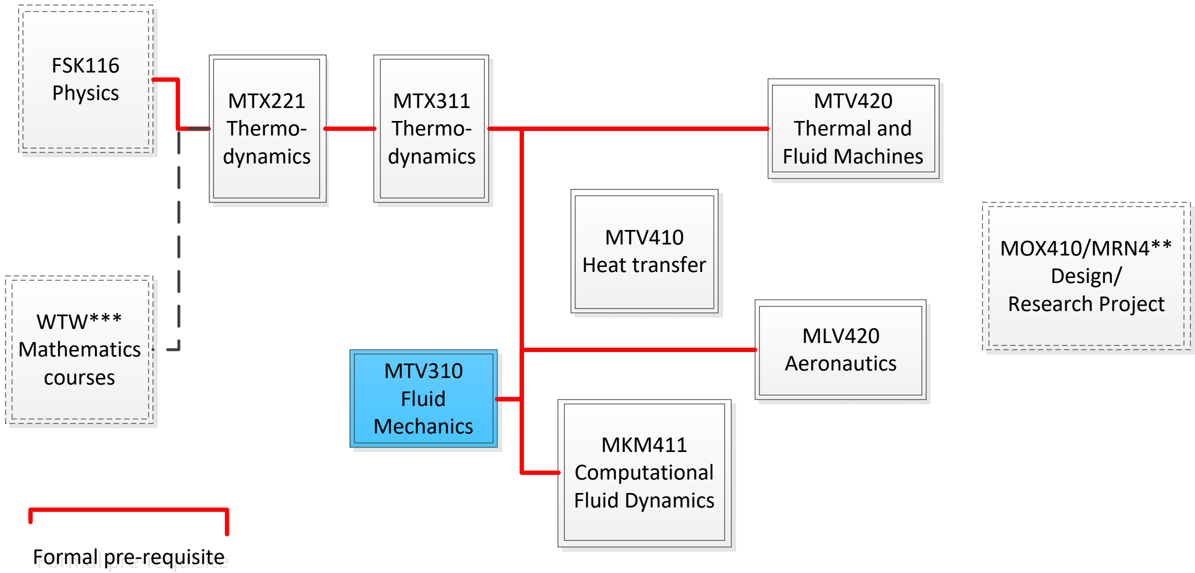
To gain exam entrance in this module, a candidate must have a semester mark of at least 40%, must attend all practicals (signature required), must sign all the relevant practical reports and must achieve at least 50% in each practical.

To pass the module, a final mark of 50% is required. A candidate must also pass assessment of ECSA Graduate Attribute (GA) 2, which will be assessed according to the document in Appendix B. The ECSA GA 2 assessment sheet will be applicable for semester tests and exams.

STUDY COMPONENT

10. INTERACTION WITH OTHER MODULES (MTV310)

Fluid Mechanics forms part of the Thermofluids theme of the Mechanical and Aeronautical Engineering course. The linkage with other modules in the degree is as follows (For the Metallurgical and Mining Engineering students, consult the curricula of your departments):



11. MODULE STRUCTURE

The module is composed from the following study units and themes:
MTV310 students to all themes. NTV310 students do themes 1 – 4.

Study theme	***Study units***	*Notional hours*	*Number of lectures*
1. Basic principles: Fluids	1.1 The concept of a fluid and the fluid as a continuum 1.2 Dimensions and units 1.3 Description of a flow field 1.4 Properties of fluids	4	3
2. Fluid statics	2.1 Pressure and pressure gradient 2.2 Hydrostatic pressure distribution 2.3 Hydrostatic pressure in gases 2.4 Manometers and barometers 2.5 Hydrostatic forces on submerged surfaces, buoyancy and stability	22	5
3. Integral approach	3.1 Closed System vs. control volume 3.2 Mass balance and energy balance 3.3 Reynolds transport theorem 3.4 Conservation of mass 3.5 Conservation of linear and angular momentum 3.6 Conservation of energy 3.7 Bernoulli equation	36	8
4. Viscous flow in ducts	4.1 Head loss and friction factor 4.2 Moody diagram 4.3 Minor losses in pipe systems	36 (18, NTV310)	7
5. Similarity and dimensional analysis	5.1 Dimensional analysis 5.2 Similarity 5.3 Experimentation and dimensionless variables	24 (0, NTV310)	5
6. Differential approach	6.1 Differential systems vs. control volumes 6.2 Conservation of mass 6.3 Conservation of momentum 6.4 Conservation of energy 6.5 Computational fluid dynamics	38 (0, NTV310)	8
	Total	**160**	**36**

12. STUDY THEME DESCRIPTIONS

STUDY THEME 1: BASIC PRINCIPLES - FLUIDS

Duration: 3 lectures

Study theme	Study topics	Section in White
1. Basic principles: Fluids	1.1 The concept of a fluid and a fluid as a continuum	1.1-1.5
	1.2 Dimensions and units	1.6
	1.3 Description of a flow field	1.7, 1.10, 1.11
	1.4 Properties of fluids	1.8, 1.9

Learning outcomes:

After completion of this study theme, the student should:

a) understand the distinction between a fluid and a solid.
b) understand the concept of a fluid as a continuum.
c) know the definition of a fluid.
d) understand and be able to use the SI units system and its basis of MLT dimensions.
e) know the definition of understand and be able to distinguish between the different ways to describe fluid motion, i.e., velocity, streamlines, pathlines and streaklines.
f) understand the definition and distinction between the different properties of a fluid and be able to distinguish between Newtonian and non-Newtonian fluids.

STUDY THEME 2: FLUID STATICS

Duration: 5 lectures

Study theme	Study topics	Section in White
2. Fluid statics	2.1 Pressure and pressure gradient	2.1-2.2
	2.2 Hydrostatic pressure distribution	2.3
	2.3 Hydrostatic pressure in gases	2.3
	2.4 Manometers and barometers	2.3-2.4
	2.5 Hydrostatic forces on submerged surfaces, buoyancy and stability	2.5-2.8

Learning outcomes:

After completion of this study theme, the student should:

a) understand the concept of pressure and that the pressure at a point is the same in all directions and to distinguish between the pressure as a variable and its consequent pressure gradient,

b) be able to evaluate the hydrostatic pressure distribution in liquids and gases,

c) understand the application of the hydrostatic pressure concepts to the principles of operation of manometers and barometers,

d) be able to apply the hydrostatic principles in evaluating hydrostatic forces on submerged surfaces, or in evaluating buoyancy forces and stability of floating and submerged objects.be able to prove that the pressure at a point in a fluid is the same in all directions.

STUDY THEME 3: INTEGRAL APPROACH

Duration: 8 lectures

Study theme	Study topics	Section in White
3. Integral approach	3.1 Closed System vs. control volume	3.1
	3.2 Mass balance and energy balance	3.1
	3.3 Reynolds transport theorem	3.2
	3.4 Conservation of mass	3.3
	3.5 Conservation of linear and angular momentum	3.4
	3.6 Conservation of energy	3.6
	3.7 Bernoulli equation	3.5

Learning outcomes:

After completion of this study theme, the student should:

a) understand the distinction between a closed system and a control volume,

b) understand the distinction between mass and energy balances for closed systems versus control volumes,

c) understand the meaning of the Reynolds transport theorem as an integral balance equation for different fluid properties, e.g. mass, energy, momentum, enthalpy, etc,

d) understand the derivation of the mass balance equation from the Reynolds transport theorem and be able to apply the resulting equation,

e) understand the derivation of the linear momentum balance equation from the Reynolds transport theorem and be able to apply the resulting equation,

f) understand the derivation of the angular momentum balance equation from the Reynolds transport theorem and be able to apply the resulting equation,

g) understand the derivation of the energy balance equation from the Reynolds transport theorem and be able to apply the resulting equation,

h) understand the derivation of the Bernoulli equation from the energy equation applicable to frictionless flow or along a streamline, and be able to apply the resulting Bernoulli equation. 3.1.2 Reynolds' transport theorem.

STUDY THEME 4: VISCOUS FLOW IN DUCTS

Duration: 7 lectures

Study theme	Study topics	Section in White
4. Viscous flow in ducts	4.1 Head loss and friction factor	6.1 – 6.3
	4.2 Moody diagram	6.4, 6.6, 6.7
	4.3 Minor losses in pipe systems	6.9, 6.10

Learning outcomes:

After completion of this study theme, the student should:

a) understand the meaning of head loss and Darcy friction factor for pipe flows,
b) be able to link between the skin friction coefficient evaluated in theme 4 and the Darcy friction factor,
c) understand the source and derivation of the laminar straight line relationship between the friction factor and Reynolds number for the laminar flow regime in a pipe,
d) understand and be able to use the Moody diagram,
e) be able to solve a variety of pipe flow problems including minor losses.be able to indicate the difference between laminar and turbulent flow in channels according to their respective losses.

STUDY THEME 5: SIMILARITY AND DIMENSIONAL ANALYSIS (MTV310 only)

Duration: 5 lectures

Study theme	Study topics	Section in White
5.Similarity and dimensional analysis	5.1 Dimensional analysis	5.1-5.4
	5.2 Similarity	5.5
	5.3 Experimentation and dimensionless variables	

Learning outcomes:

After completion of this study theme, the student should:

a) understand the reasons for the need to use dimensional analysis,
b) be able to transform the Navier-Stokes equations into a dimensionless form,
c) be able to express the analytical solutions derived in theme 4 into their dimensionless form,
d) be able to apply similarity conditions when planning simple fluid dynamics experiments
e) be able to process experimental results into dimensionless form

STUDY THEME 6: DIFFERENTIAL APPROACH (MTV310 only)
Duration: 8 lectures

6 Differential equations for a flow particle	6.1 Differential systems vs. control volumes	6.1.1 The particle approach	4.1
		6.1.2 Solution of the differential equations	
	6.2 Conservation of mass	6.2.1 General formulation	4.2
		6.2.2 Cylindrical co-ordinates	
	6.3 Conservation of momentum	6.3.1 General formulation	4.3
		6.3.2 Cylindrical co-ordinates	
		6.3.3 Navier-Stokes and Euler equations	4.9, 4.10
	6.4 Conservation of energy	6.4.1 General formulation	4.5
	6.5 Computational fluid dynamics		

Learning outcomes:

6.1 Differential systems vs. control volumes

6.1.1 The particle approach

After completion of this study theme, the student should:
a) understand what is meant by the particle approach and be able to explain it.
b) be able to motivate the use of the differential approach by using practical examples.

6.1.2 Solution of differential equations

After completion of this study theme, the student should:
a) take note of the methods that are used to solve for the differential equations.
b) take note of the relative success and degree of difficulty when using the different methods for solving the differential equations.

6.2 Conservation of mass

6.2.1 General formulation

After completion of this study theme, the student should:
a) be able to derive the general formulation for the conservation of mass for an infinitesimal control volume from that of a finite control volume and be able to explain the meaning of each term.
b) be able to reduce the above equation so that it is valid for steady flow.
c) be able to reduce the above equation so that it is valid for steady incompressible flow.
d) know and be able to write down all the above equations in vector algebra notation..

6.2.2 Cylindrical co-ordinates

After completion of this study theme, the student should:

a) be able to recognise the general formulation for mass conservation for an infinitesimal control volume in cylindrical co-ordinates.

6.3 Conservation of momentum

6.3.1 General formulation

After completion of this study theme, the student should:

a) be able to derive the general formulation for the conservation of momentum for an infinitesimal control volume from that of a finite control volume and be able to explain the meaning of each term.
b) be able to reduce the above equation so that it is valid for steady flow.
c) be able to reduce the above equation so that it is valid for steady incompressible flow.
d) know and be able to write down all the above equations in vector algebra notation..
e) able to apply all the above equations in calculations.

6.3.2 Cylindrical co-ordinates

After completion of this study theme, the student should:

a) be able to recognise the general formulation for momentum conservation for an infinitesimal control volume in cylindrical co-ordinates.

6.3.3 Navier-Stokes and Euler equations

After completion of this study theme, the student should:

a) know the assumptions required to reduce the general formulation for momentum conservation for an infinitesimal control volume to the Navier-Stokes equation and be able to perform this reduction.
b) know the assumptions required to reduce the general formulation for momentum conservation for an infinitesimal control volume to the Euler equation and be able to perform this reduction.
c) be able to show how the Navier-Stokes equation reduces to the basic equation of hydrostatics using the correct assumptions.

6.4 Conservation of energy

6.4.1 General formulation

You should take note of the general differential formulation for the conservation of energy for an infinitesimal control volume.

6.5 Computational Fluid Dynamics

6.5.1 Introduction
6.5.2 Finite difference, finite volume and finite element approaches
6.5.3 Level of approximation, transformation to curvilinear co-ordinates
6.5.4 Typical applications and current capabilities

Appendix A: REGULATIONS REGARDING PRACTICALS

General

a) Practicals 1-2 each take approximately 30min to complete. Practical 3 is done in the students' own time and should take approximately one day.

b) Times for practicals 1-2 will be chosen by groups after construction of the groups during the first two weeks of lectures. Practicals start after an announcement to this effect. The due date for Practical 3 will be announced on ClickUP.

c) Groups that are not well-prepared may be refused entrance to the practical sessions.

d) Each group must perform all three practicals.

e) Each student must attend each of practical 1 and 2 (confirmed by signature on teaching assistant's sheet).

f) A sub-minimum of 50% for each practical is required for exam entrance.

g) No student will be exempt from any practical. This includes repeating students.

h) Closed shoes are to be worn for Lab practicals.

Reports

a) Document your findings in detail. Your report should typically include the following:

Aim/Motivation (complete)
Method
Results
Conclusion and evaluation (Extremely important!)

b) Hand in a ***group*** *report* within **5 lecture days** after completing practicals 1-2. **10%** will be subtracted from the mark for each day a report is **late**.

c) Each report must have a standard cover page (refer to Plagiarism in Departmental Study Guide). The signature of each student in the group **must** be on the report. You are being trained to be professional engineers and must learn to assume responsibility for your own work. **Add a column to the cover page where the percentage contribution of each member is indicated**. Example for 4 members of group where all group members participated equally by consensus:

Student details / Studentebesonderhede				
Student number **Studentenommer**	**Initials and surname** **Voorletters en van**	**Signature** **Handtekening**	**Date** **Datum**	**% contribution**
Student A				25%
Student B				25%
Student C				25%
Student D				25%

Appendix B: ECSA GRADUATE ATTRIBUTE 2

University of Pretoria
Department of Mechanical and Aeronautical Engineering
MTV310 Fluid Mechanics/NTV310 Metallurgical Fluid Mechanics
Assignment, Practical, Test and Exam Outcome Evaluation Sheet

Evaluation in terms of ECSA Graduate Attributes as per ECSA document PE 61 section 2. Graduate Attribute 2 is considered critical and must be passed.

<u>Graduate Attribute 2: Application of scientific and engineering knowledge</u>
The student must demonstrate competence to apply knowledge of mathematics, basic science and engineering sciences from first principles to solve engineering problems.

1. Brings mathematical, numerical analysis and statistical knowledge and methods to bear on engineering problems by using an appropriate mix of:
   - 1.1 Formal analysis and modeling of engineering components, systems or processes.
   - 1.2 Communicating concepts, ideas and theories with the aid of mathematics.
   - 1.3 Reasoning about and conceptualizing engineering components, systems or processes using mathematical concepts.
   - 1.4 Dealing with uncertainty and risk through the use of probability and statistics.
2. Uses physics laws and knowledge of the physical world as a foundation for the engineering sciences and the solution of engineering problems by an appropriate mix of:
   - 2.1 Formal analysis and modeling of engineering components, systems or processes using principles and knowledge of the basic sciences.
   - 2.2 Reasoning about and conceptualizing engineering problems, components, systems or processes using principles of the basic sciences.
3. Uses the techniques, principles and laws of engineering science at a fundamental level and in at least one specialist area to:
   - 3.1 Identify and solve open-ended engineering problems.
   - 3.2 Identify and pursue engineering applications.
   - 3.3 Work across engineering disciplinary boundaries through cross disciplinary literacy and shared fundamental knowledge.

Evaluation Matrix to assess ECSA Graduate Attribute (GA) 2:

Has the student used a correct and logical method to solve the problem?	√	X
Has the student shown all working in his/her derivation to achieve the solution?	√	X
Has the student made all the necessary assumptions to solve the problem?	√	X
Has the student explained his/her reasoning behind using the relevant equations/method to solve the problem?	√	X
Has the student considered if the solution is viable in practice under physics laws in the physical world?	√	X
Has the student made correct numerical approximations?	√	X
Result	√	X

The student must pass a minimum of 3 ticks (√) and a total of 50% averaged over all questions to achieve GA 2. This matrix will be attached to each semester test and exam.