UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie

Department of Mechanical and Aeronautical Engineering

MACHINE DESIGN
MOW 312

Lecturer: R. J. Huyssen
Last Revision: February 2019

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Note: Throughout this document 'the student' or 'he' or 'him' is implied to include 'she' or 'her'

1. OBJECTIVE OF THIS COURSE

Engineering design is the general process of developing solutions to engineering problems or challenges. Design is therefore considered to be the core faculty of an engineer. The group of design modules running through the entire curriculum (of which this module is part) should thus be considered as very important in the development of an engineer in that it intends to integrate the art learned in school and in other courses to be applied in *the art of problem solving*.

It is the objective of this first semester course to show you the bigger picture of the *solution development process* and to show how this process systematically narrows down a problem (challenge) to the level of detail design at the piece-part's level. As design engineer you need to be aware of your responsibility to understand, formulate and then to remain focused on the actual problem and to select conceptual solutions systematically, creatively and wisely on the road to the detail solution. You need to develop self-confidence in this open-ended process in which *you need to guide yourself* by your ability of rational reasoning and lateral thinking. You should be stimulated to enhance your curiosity in discovering the actual causes behind effects and to unlock your creativity to discover the best causes to achieve a desired outcome. You will be encouraged to improve your skill of visualizing and systematically describing systems in diagram, in word, in sketch and in mathematical model.

You shall discover that the design engineer manages an innovation process of which much detail can be contracted to specialists. While you will be briefly exposed to selected specialist themes, it is not the objective of this course to make you a specialist in such themes but rather to use these in examples of steps in the design process. Some such specialist themes are addressed more deeply in other courses. It is assumed that you are able to apply your skill of self-study to familiarize yourself with knowledge, method and procedure consolidated in handbooks, manuals, regulations, codes, computer codes and other sources of collective information.

In this course you will be expected make the leap to independence: You may have previously received clear instructions for specific tasks to know what to do, now you will be challenged to *discover yourself what needs to be done from deliberately vague descriptions of problems*.

Design is normally associated with systems, therefore this module will be cast into a framework of *Systems Engineering*. Solutions are often developed in *teamwork* and therefore the opportunity of teamwork is an important objective of this course. The focus is not on teaching much new material but on offering the opportunity for unlocking the skill of integrating the things you already understand.

Our world is facing many serious challenges. It is the objective of this course to lay a foundation of awareness and systematics on which you, the future engineer, educator and team leader can build the capacity to make a positive difference in this world. It is hoped that some of you will guide your carriers to become recognized for contributions at alleviating some big challenge in our world. Please join this challenge with eagerness for this intent.

2. LECTURER AND CONSULTING HOURS

	Name	Building / Office	Phone No.	Email Address
Lecturer	Mr. R. Joachim Huyssen	Eng I, room 9-19	012 420 2192	joachim.huyssen@up.ac.za
Guardian	to be announced			
TA	Mr. M. Meyer			
TA	Mr. N. Jansen van Vuuren			
TA	t.b.a			
TA	t.b.a			

The venues for lectures and tutorial sessions are disclosed in the departmental timetable.

Consulting hours

The lecturer will be available after class and after the tutorial session for half an hour for ad hoc consultation (unless announced otherwise). You are very welcome to use this opportunity in which also an alternative can be arranged. Any other hour in the week which may be arranged by the class representative will be announced and will be displayed on the office door. Please consult the lecturer only during these declared consulting hours, or else strictly by confirmed appointment only. This provision also holds close to the time of tests and examinations. You are therefore encouraged to manage your time well and to work continuously throughout the semester and come for consultation as early as necessary.

You are advised to discuss any issues with fellow students and to organize group consultations or to raise issues in class as these are likely to be of benefit to all students.

Tutorial sessions are intended also for questions and discussions arising from the work, the homework and the assignments and offer a useful opportunity for individual or group consultation, please make good use of it.

Issues in the course

Any issues whatsoever relating to this course should be discussed with the lecturer as soon as such become apparent! If for some reason you prefer, you may discuss it with the class representative instead who shall take it up with the lecturer as soon as possible. If the issues cannot be resolved in this way the class representative shall approach the class guardian, who shall then take the issues up with the lecturer or, if necessary, escalate it appropriately. Any escalation directly to the head of department is extremely disruptive and you will be required to demonstrate that you have followed the correct procedure. Failing this may suggest that you have not familiarized yourself with the content of this guide.

3. STUDY MATERIAL

The following study material is required:

- Notes of the previous courses of Machine Design (MOW 217 and 227),
- Shigley's Mechanical Engineering Design, 10th edition (9th or later also suitable), by Richard G. Budynas; J. Keith Nisbett

Additional notes may be provided electronically during the course of the semester.

4. LEARNING ACTIVITIES

4.1 Contact time and learning hours

There will be 3 lectures per week (total of 36 lectures).
There will be one 3 hour tutorial session per week (total of 10 sessions).

As a 16 credit module the student is expected to spend some 160 hours to master the required skills (including time for preparation of tests and examinations). The contact time is approximately 4 to 6 hours per week. The student is advised to devote another 8 hours per week of own time to this module to study, prepare and work on assignments.

4.2 Lectures

Lectures are intended to guide the student through a selection of themes and to put these into the wider context of system engineering. Brief clarification and explanation of the subject matter and concepts are given during the lectures. The lectures outline the scope of the field to guide the student in his self-study of the study material. Questions arising from the self-study and from assignments can be addressed during the tutorial sessions. Students are required to prepare for tutorial sessions as guided by the homework instructions.

4.3 Tutorial sessions and assignments

The class will be enrolled into teams of 6 to work on group assignments. It is important that group members will have regular meetings on campus. Teams should organize themselves as a small design company that is working on the design project which will be done throughout the semester. The teams are expected to sit together during the tutorial session and to progress on work on the project. Each team must have at least one member present at each formal session. The scheduled time of each tutorial session shall be kept available by all students for this purpose.

Group assignments will be handed out in class as homework to serve as examples of the ideas which have been outlined in class and studied at home. There will be a gradual progression through the design process as this is implemented on some aspects of the development of a design. Tutorial sessions should be seen as design review meetings. Assignments need to be handed in at the beginning of the declared tutorial session. These will then be discussed and some will be peer evaluated.

Another objective of the tutorial sessions is to offer a chance to elaborate on work in class as deemed necessary. Students are therefore encouraged to ask questions, discuss difficulties or raise matters of interest on the topics. These sessions will also be used to discuss the semester tests. Students are advised to participate actively in discussions during tutorial sessions. The lecturer will be available for one-on-one consultation and assistance to students at the end of tutorial sessions.

To make the most of these sessions the student must be prepared. During some of these sessions

a small unannounced class test may be written on work which had been assigned for self- study. Their marks will contribute to the semester mark.

These sessions are challenging to manage given the large size of the group. Your kind cooperation and consideration to others is required at all times. All team communication should be limited to periods allowed for this purpose and all are required to keep the noise levels to a minimum. If good cooperation is given a session can be concluded earlier than otherwise! Teams are advised to use this time in their timetable to conclude their meetings even if somewhere else after the tutorial session. Team meetings must be conducted on campus.

5. ASSESSMENT

Also see the examination regulations in the Year Books of the Faculty of Engineering, Built Environment and Information Technology (Part 1: Engineering, or Part 2: Built Environment and Information Technology).

Pass requirements:

In order to pass the module a student must obtain a final mark of at least 50%, and an average for the assignments (after peer evaluation) of at least 50%.

Semester mark:

Semester tests counts:	60%
Assignments add up to:	40%
Class tests contribute:	5% towards the mark for assignments

Final mark:

Semester mark counts:	50%
Examination mark counts:	50%

For admission to the exam <u>both</u> these conditions must be met:

- A semester mark of at least 40%
- A minimum of 50% for the accumulated mark for the assignments (after peer evaluation)

Semester tests: Two tests will be written during the scheduled test weeks of the School of Engineering. Dates, times and venues will be published in the timetables.

Any absence from semester tests must be dealt with in accordance with the sick test guidelines of the departmental study guide (see the link below). Additionally, the lecturer shall be informed by the student by email immediately after the missed test to be registered for a special semester test which will be taken after the second test week. This will be based on all the work done in the module up to that time. The date for this special test will be arranged and announced only to registered absentees.

Homework: Some specific homework will be given which every student is expected to do on his own. While this will not be assessed individually it may become useful for doing the assignments. Team members will then assess such work amongst each other to select and improve the best contribution for inclusion in their group assignment. In this way the homework may become assessed.

Assignments: The mark for assignments will contribute to the semester mark in proportion to their complexity as will be announced later and may be adjusted according to the peer evaluation.

Tutorial Sessions: Students are required to attend all scheduled tutorial sessions. Failing this may result in a zero score for the class test of that session.

Class tests: A few class tests may be written during some of the tutorial sessions on homework which has been assigned for self-study. These tests will not be announced.

Lectures: Students are required to attend all lectures as this is not a correspondence course. Tests and examinations will include questions which reflect on work discussed only in class or in the tutorial sessions. Student attendance will be recorded during every lecture. Special examinations will not be considered for students who have a poor attendance record. In the case of any dispute about passing the course the attendance record shall be used to demonstrate satisfactory attendance to decide the case.

Peer Evaluation: Although group work will be required, students must produce their own work. Under no circumstance is a student allowed to copy the work (or part thereof) from somebody else and claim it to be own work. Member contributions need to be clearly acknowledged in the assignment reports. The name of non-contributing members shall not appear as co-author on a report. Peer evaluations will be done after each assignment. These evaluations will be used to up- or down-grade the individual score for assignments if necessary. Note, team members who did not contribute sufficiently to the assignments can thus be failed by their peers and may fail to be admitted to the final examination! This means failing the module without having an opportunity to resolve this shortfall.

6. USE OF ELECTRONIC DEVICES

Students are encourage to take notes by pen in a paper notebook during class. If an electronic device is to be used instead, please discuss this with the lecturer in advance as the use of such devices during class is otherwise not permitted. Any appropriate electronic device may be used during tutorial sessions for relevant activities. During tests and examinations only authorised calculators are permitted.

7. MODULE STRUCTURE

This module will be treated within a framework of Systems Engineering. Within this frame the design philosophy and design process will be addressed in the context of the organizational environment. Within this framework a selected variety of detail themes will be addressed as described below. These themes serve as examples to develop some steps within the design process. The detail of the themes is treated with emphasis on self-study. The lecture will add peripheral context to these themes not visible in the handbook or the online study material. The student is expected to take own class notes. Class attendance is therefore required.

8. 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 exit level outcomes, 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:

https://www.up.ac.za/media/shared/120/ZP_Resources/Noticeboard/departmental-studyguide-eng-2019_version29-jan2019.zp167517.pdf

https://www.up.ac.za/media/shared/120/ZP_Resources/Noticeboard/departementele-studiegids-afr-2019_weergawe29-jan2019.zp167518.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 during a test or examination (very important)
d. Appeal process on the adjustment of marks.

9. STUDY THEMES

The following lists the themes which will receive special emphasis during this course. These themes serve as examples of typical special fields of expertise towards which one could specialize. This overview of 1 to 3 lectures on each theme, is not sufficient to make the student an expert in that field but it creates a proper awareness of the theme and how one may approach a challenge involving that theme.

9.0 Module Framework: SYSTEMS ENGINEERING

Learning outcomes

As the module framework this theme runs alongside all other themes throughout the semester to outline the design process. The student shall discover the bigger picture of system engineering and will learn how a problem or challenge becomes gradually narrowed down until the final steps of detail design can be taken. The student shall learn that the design engineer has to coordinate a large variety of activities in the design process of which detail design can often be done by specialists in their relevant fields. He will not be expected to become such a specialist in any specific field but rather understand how to integrate all his knowledge into the process of design. At the end of the semester the student shall:

a. have a good understanding of systems engineering.
b. understand the typical steps of the design process and the relevant documents.
c. have organized the basic building blocks of an energy systems.
d. understand the importance and the role of systems analysis and functional analysis.
e. be comfortable to compile a functional analysis at various levels of a system.

Study units for self-study

Study any material on the topic of systems engineering. Derive from first principles the basic building blocks of an energy systems.

Assignment for assessment

All assignments shall be done in the context of system engineering and shall respect the importance and involvement of literature study and the system and functional analysis as the basis of all design activities.

9.1 Theme 1: HUMAN FACTOR AND ERGONOMICS

Learning outcomes

After the completion of this study theme the student should:

a. understand important physiological factors which influence human performance.
b. understand the importance of safety and health which need to be respected at all times.
c. be able to interpret and use anthropometric and biomechanics data to prepare specifications for machine elements which interface with the human operator or user.
d. have a good overview of the field of human factor and ergonomics.
e. be able to apply the design guidelines for vehicle occupant protection.

Study units for self-study

Study and understand the use of all study material as provided.

Assignment for assessment

The assignment will require the student team to prepare a part of a design specification which requires the selection and interpretation of ergonomic data to specify the limits of available work for the operation of a system activated by a human user.

9.2 Theme 2: STRUCTURAL DESIGN

Learning outcomes

The student is expected to understand and apply the first principles approach in engineering structure design as offered in other courses. He must however also be aware of the regulations which govern every field of engineering. He must be aware of the existence of design codes and regulatory requirements with which the design engineer needs to comply. Here an overview will be given as to how the modern field of engineering is regulated by authorities and certification requirements. Some examples of regulations and design codes will be given.

The purpose of this study theme is:

a. to introduce the realm of regulatory authorities and certification.
b. to introduce the method of code based design.
c. to introduce the concept of limit state design as an alternative to stress based design.
d. to understand the difference between serviceability- and ultimate limit states.
e. to understand and apply the load factors, safety factors and resistance factors.
f. to introduce the notion of load paths and load path efficiency.

Study units for self-study

Study the example code which will be recommended.

Assignments for assessment

As a team assignment the theme of structural design will be used in an example of preliminary structural sizing. This will require the definition of load cases, the formulation of a safety factor policy, the consideration of load path efficiency and structural layout design and some basic strength calculations.

9.3 Theme 3: PRESSURE VESSELS

Learning outcomes

After completion of this self-study theme, the student should:

a. know the elements of a pressure vessel system.
b. be able to analysing the pressure vessel wall stresses.
c. understand the function and the risk of the pressure vessel.
d. understand the role of the regulations and codes in the design, manufacture, modification, repair, use and operation of vessels under pressure.
e. be able to assess the energy density of the system under pressure.
f. be able to apply model the polytropic process of compression and expansion.

Study units for self-study

Study and understand the relevant sections from the Occupational Safety Act (Act 6 of 1983). Understand how the regulations make reference to the pressure vessel codes and how these shall be applied during the design of vessels under pressure.

Assignments for assessment

As a team assignment the theme of pressure vessels will be used in an example where the energy capacity needs to be estimated. This will require the basic strength calculations and interpretation of the regulations and the understanding of the polytropic process.

9.4 Theme 4: WELDING AND BONDING

Learning outcomes

After completion of this study theme, the student should be capable to:

a. choose a suitable joining method.
b. understand the different welding techniques.
c. understand the implications of welding joints.
d. analyse and specify welded joints.
e. understand the challenges and opportunities of bonding.

Study units for self-study

Study Shigley chapter 9

Assignments for assessment

A team assignment involving welding, heat treatment and non-destructive testing will address this theme.

9.5 Theme 5: HEAT TREATMENT OF MATERIALS

Learning outcomes

After completion of this study theme, the student must be able to:

a. select an appropriate steel for a given requirement.
b. specify a suitable heat treatment for a specified objective.
c. understand the material properties resulting from different heat treatment processes.

Study units for self-study

Review chapter 2 in Shigley with specific emphasis on the subsections relating to heat treatment. Additional electronic study material will be provided.

Assignments for assessment

A team assignment involving welding, heat treatment and non-destructive testing will address this theme.

9.6 Theme 6: NON-DESTRUCTIVE TESTING

Learning outcomes

After completion of this study theme the student must be capable to:

a. distinguish between the different techniques of non-destructive testing.
b. understand the suitability of various NDT techniques.
c. specify relevant NDT technique for specific objectives.

Study units for self-study

A guest lecturer will provide supplementary study material.

Assignment for assessment

A team assignment involving welding, heat treatment and non-destructive testing will address this theme.

9.7 Theme 7: GEARS AND GEAR SYSTEMS

Learning outcomes

After completion of this study theme the student should be capable to:

a. choose suitable gear train arrangement and gear types.
b. design an appropriate gear system for a specified application.
c. design a gear set for strength and against surface failure.
d. provide for the load path through a gearbox.
e. understand the energy implications of a gearbox.

Study units for self-study

Shigley, Chapters 13, 14 and 15.

Assignments for assessment

In a team assignment the team will be expected to do a preliminary design a gearbox as part of a transmission system of a small vehicle drive train. Contact stresses and lubrication issues need to be considered as well.

9.8 Theme 8: CONTACT STRESSES

Learning outcomes

After the completion of this study theme the student should be capable to:

a. calculate the contact stresses in spherical or cylindrical surfaces in contact.
b. apply different failure criteria.
c. Specify the necessary surface hardness to enable durability against induced stresses.

Study units for self-study

Relevant content in Shigley on contact stresses (Chapter 3.19).

Assignment for assessment

Contact stresses and lubrication issues need to be considered in the preliminary gearbox design of the same team assignment of above.

9.9 Theme 9: LUBRICATION / TRIBOLOGY

Learning outcomes

After completion of this study theme the student should:

a. understand the principles of tribology.
b. understand the properties of lubricants.
c. know the different types of lubrication.
d. understand the hydrodynamic theory.
e. be able to calculate the temperature rise in bearings.

Study units for self-study

Relevant content in Shigley about lubrication (Chapter 12 and other subsections).

Assignment for assessment

Contact stresses and lubrication issues need to be considered in the preliminary gearbox design of the same team assignment of above.

10. Appendix

Assessment of Exit Level of ECSA Outcome 8

Exit level outcome 8: Individual, team and multidisciplinary working

Learning outcome: Demonstrate competence to work effectively as an individual, in teams and in multidisciplinary environments.

Associated Assessment Criteria:
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The candidate demonstrates effective individual work by performing the following:
1. Identifies and focuses on objectives;
2. Works strategically;
3. Executes tasks effectively;
4. Delivers completed work on time.

The candidate demonstrates effective team work by the following:
1. Makes individual contribution to team activity;
2. Performs critical functions;
3. Enhances work of fellow team members;
4. Benefits from support of team members;
5. Communicates effectively with team members;
6. Delivers completed work on time.

The candidate demonstrates multidisciplinary work by the following:
1. Acquires a working knowledge of co-workers' discipline;
2. Uses a systems approach;
3. Communicates across disciplinary boundaries.

Range Statement: Tasks require co-operation across at least one disciplinary boundary. Disciplines may be other engineering disciplines or be outside engineering.

Evaluation Matrix to assess ECSA Exit level of Outcome 8:

Has the student identified and focused on the objective?	√	X
Did the student work strategically?	√	X
Has the student executed the task effectively?	√	X
Has the student delivered completed work on time?	√	X
Has the student made individual contributions to the team activity?	√	X
Has the student performed critical functions?	√	X
Has the student enhanced the work of fellow team members?	√	X
Did the student benefit from support of team members?	√	X
Has the student communicated effectively with team members?	√	X
Has the student acquired a working knowledge of co-workers' disciplines?	√	X
Has the student used a systems approach?	√	X
Has the student communicated across disciplinary boundaries?	√	X
Result	√	X

The student must pass a minimum of 6 ticks (√) and a total of 50% averaged over all questions to achieve Outcome 8.

Summary of Contact Time and Notional Time

Study Theme		**Notional Hours**	**Contact Session**
0 Systems Engineering	Lectures, tutorials, assignments	16	10
1 Ergonomics	Lectures, tutorials, assignments	24	8
2 Structural Design	Lectures, tutorials, assignments	20	8
3 Pressure Vessles	Lectures, tutorials, assignments	32	8
4 Welding	Lectures, assignments	12	6
5 Heat Treatment	Lectures, assignments	8	4
6 NDT	Lectures, assignments	8	4
7 Gears	Lectures, tutorials, assignments	32	8
8 Contact Stresses	Lectures, assignments	4	2
9 Lubrication	Lectures, assignments	4	2
	Total	**160**	**60**

Note: The notional time includes the contact time of 36 lectures and 10 tutorial sessions. Additional time will be spend on homework, assignments, and preparation for tests and examinations.