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
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1. Course Objectives

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 what has been learned in school and in other courses to be applied to *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 parts level. As a design engineer, you need to be aware of your responsibility to understand, formulate and then 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 the desired outcome. You will be encouraged to improve your skill of visualizing and systematically describing systems in diagrams, words, sketches and mathematical models.

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 can 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 to 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*. Previously answers to problems may have been provided. Now you are expected *to assess the quality of your answers on your own*.

Design is normally associated with systems, therefore this module will be cast into a framework of *Systems Engineering*. Solutions are often developed by *teamwork* and therefore the opportunity of teamwork is an important part of this course. The focus is not on teaching much new material but on offering the opportunity for unlocking the skill of organising and integrating the material you already know and understand and to apply such understanding to the problem-solving process.

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 to 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	Dr. R. Joachim Huyssen	Eng I, room 9-19	012 420 2192	joachim.huyssen@up.ac.za
TA	to be announced			

Consulting Hours

The lecturer will be available after class and at the end of the tutorial session for half an hour for ad hoc consultation (unless announced otherwise). You are very welcome to use this opportunity during which also an alternative time can be arranged. Any other consultation can be arranged 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 work continuously throughout the semester and come for consultation as early as necessary.

You are encouraged 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 lectures, the homework and the assignments and offer a useful opportunity for individual or group consultation, please make good use of it. Do not wait till too late.

The best value in terms of learning can be added in direct consultation when specific technical issues could not be resolved by consultations with peers or other sources. For this purpose, your lecturer or his teaching assistants are available for discussion. *Please make use of this important opportunity as an enrolled student to seek in-person consultation*.

Issues in the Course

Any issue whatsoever relating to this course should be discussed with the lecturer as soon as such becomes 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 issue cannot be resolved in this way the class representative shall approach the class guardian, who shall then take the issue 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. You are expected to address issues yourself without the involvement of your parents or guardians.

3. Study Material

The following textbook is prescribed for this course:

- *Shigley's Mechanical Engineering Design*, 10th edition (9th edition or later), by Richard G. Budynas; J. Keith Nisbett

Additionally, the following textbook is recommended (available from the library):

- *The Mechanical Design Process*, 4th edition, by David G. Ullman

Additional notes and references may be provided electronically during the semester.

You are encouraged to use credible sources on the Internet to explore the topics further.

4. Learning Activities

4.1 Lectures, Tutorial Sessions and Learning Hours

There are three lecture timeslots per week allocated to this course for a total of 36 lectures. Additionally, the timetable provides for a three-hour tutorial session per week in which the group work can progress. The times and venues for lectures and tutorial sessions are disclosed in the departmental timetable. Initial lectures will be held online until reasonable contact sessions can be held on campus pending the status of the lock-down and the decisions taken by UP management. Online sessions will make use of the BlackBoard Collaborate Course Room on ClickUp. Course Notes for the week will be available on ClickUp before the lectures and Recordings can be downloaded under the Cours Room Menu after the lectures. Announcements and the Notice Board on ClickUp will be used to communicate the mode of lectures.

As a 16 credit module, you are 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. **You are advised to devote additional 8 hours per week to this module** to study and prepare, to do your homework and to work on assignments.

4.2 Lectures

Lectures are intended to guide you 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 you in your self-study of the study material.

4.3 Tutorial Sessions and Assignments

Tutorial Sessions

Questions arising from the self-study and assignments can be addressed during the tutorial sessions. You are required to prepare for tutorial sessions as guided by the homework instructions.

Another objective of the tutorial sessions is to offer a chance to elaborate on work in class as deemed necessary. You 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. **All students are advised to participate actively in discussions during tutorial sessions.** The lecturer will be available for one-on-one consultation and assistance at the end of the tutorial sessions.

To make the most of these sessions you must be prepared. During some of these sessions, a small unannounced class test may be written on work that had been assigned for self-study. Their marks will contribute to the semester mark.

Assignments

The class will be enrolled in groups of 5 to work on consecutive Group Assignments. It is compulsory that Group members conduct regular meetings while preparing the Group Assignments. Groups should organize themselves as a small design company that is working on the design projects throughout the semester. The Groups are expected to use the time of the tutorial session and to progress on work on the project. Each Group must have at least one member present at each formal session. The **full three hours of 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 via ClickUp strictly before the respective submission deadlines. **Late submissions will not be marked**. Assignments will then be graded by peer assessment by other groups.

Together with the submission of each Assignment, each Group must submit a peer evaluation (the Team Contribution Declaration) in which the contributions by each Group Member are clearly mentioned. Each member must make an equal technical contribution to earn the mark for the assignment. Administrative or editorial tasks do not qualify as technical contributions. **NOTE! you can fail this course if you do not meet the subminimum requirement for this course in terms of group work as described below.** If your participation and your contributions towards the group effort have been insufficient **you will not be admitted to the exam** and **there is nothing that can be done to fix this retrospectively**!

Group Members who fail to attend meetings or do not make their contributions on time or with sufficient quality must be warned in writing (by email) by a representative of the group. If their participation or contribution remains poor, this must be noted honestly in the Team Contribution Declaration. Declaring a contribution higher or better than made in reality would be dishonest conduct and will be held against those making the dishonest declaration.

Each Group Member must participate in the peer assessment of assignments by other groups. Failing to do so will result in a lower mark for the non-participating member for their own assignment. Low quality or dishonest assessment will be considered as non-participation in the assessment process.

Groupwork is challenging to manage if some members are not responsive, diligent or punctual. **Such problems must be addressed early and proactively** to ensure that Groups can demonstrate competent and effective teamwork as required for the ECSA Graduate Attribute 8 described below. ECSA requires that students failing on this Attribute must repeat the course! Groups are advised to use the timeslot of the tutorial session to conduct their meetings. Professional meeting ethics and procedures must be applied!

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:

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:	60%
Assignments:	40%
Class tests:	5% contribution towards the mark for assignments

Final Mark:

Semester mark:	50%
Examination mark:	50%

For admission to the examination both 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 and times will be published as for other courses.

Any absence from semester tests or the examination must be dealt with in accordance with the sick test guidelines of the Departmental Study Guide (see the link below). Student administration will compile a list of students who qualify for the sick test. Students failing to get onto this list will not be admitted to the sick test! Additional to the departmental procedure, the lecturer shall be informed by the student by email immediately after the missed test of the reason for having failed attendance of the test. The sick test 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 you are expected to do on your own. While this will not be assessed individually it may become useful for doing the assignments. Group 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. You are encouraged to compare your homework results with those of fellow students in your group.

Assignments: The mark for assignments will contribute to the semester mark in proportion to their complexity as will be announced. The individual mark may be adjusted according to the peer evaluation and the participation in the peer assessment of assignments by other groups.

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 as well as poor peer evaluation.

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

Lectures: Students are required to attend all lectures. Tests and examinations will include questions that reflect on work discussed only in class or in the tutorial sessions. Student attendance will be recorded. 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 assess attendance to help decide the case.

Peer Evaluation: In this module ECSA Graduate Attribute 8 is of specific importance, therefore, all assignments will be done as group work. However, students are still required to contribute by 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 their 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, Group 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, thus failing the module without having an opportunity to resolve this shortfall.

6. Session Recordings

Students are encouraged to take notes by pen in a paper notebook during lectures. Session recordings may fail and should not be relied upon. Class notes serve only as a summary of the points addressed. Session recordings are intended as a backup for those, who had momentary circumstances which prevented attendance of the live session. The recordings are not to be considered as a substitute for the live session under normal circumstances! Listening to a session recording does not constitute class attendance.

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. Students are expected to take their 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, grievances, support services, plagiarism, class representative duties, sick test and sick exam guidelines, vacation work, the appeal process and adjustment of marks, university regulations, frequently asked questions), 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 on the Department's website:

https://www.up.ac.za/media/shared/120/Noticeboard/2021/departmental-studyguide-eng-2021_version26feb2021.zp199803.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 you 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. You 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. You 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. You will not be expected to become such a specialist in any specific field but rather understand how to integrate all your knowledge into the process of design. Through your participation during the the semester you shall:

a. have a good understanding of the role of systems engineering.
b. understand the typical steps of the design process and their relevant documents.
c. have organized the basic building blocks of 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 energy systems and organize these into a comprehencive mind map.

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 you 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 source anthropometric and biomechanics data.
d. be able to interpret and use anthropometric and biomechanics data to prepare specifications for machine elements that interface with the human operator or user.
e. have a good overview of the field of human factor and ergonomics.
f. be able to apply the design guidelines for occupant protection in vehicles.

Study units for self-study

Study all material provided.

Assignment for assessment

The assignment will require the student team to participate in a data collection survey, to interpret the collected data and to prepare a part of a design specification that requires such ergonomic data

to specify the limits of available work and power for the operation of a system activated by a human user.

9.2 Theme 2: Structural Design

Learning outcomes

You are expected to understand and apply the first principles approach in engineering structure design as offered in other courses. You must however also be aware of the regulations which govern every field of engineering. You 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 concept of limit state design as an alternative to stress-based design.
c. to understand the difference between serviceability- and ultimate limit states.
d. to understand and apply the load factors, safety factors and resistance factors.
e. 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 group 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, you should:

a. know the elements of a pressure vessel system.
b. be able to analyse 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 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 and commissioning of vessels under pressure.

Assignments for assessment

As a group 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 thermodynamic polytropic processes.

9.4 Theme 4: Welding and Bonding

Learning outcomes

After completion of this study theme, you must:

a. be capable to advise a suitable joining method.
b. understand the different welding techniques.
c. understand the implications of welding joints.
d. be able to comment on the variety of welding defects.
e. be able to analyse and specify welded joints.
f. understand the challenges and opportunities of bonding.

Study units for self-study

Study Shigley chapter 9. Look at videos demonstrating various welding techniques.

Assignments for assessment

A group assignment involving welding, heat treatment and non-destructive testing will address these themes.

9.5 Theme 5: Heat Treatment of Materials

Learning outcomes

After completion of this study theme, you must:

a. have a good overview of the topic
b. respect the importance of material selection
c. know the options of treatment processes
d. understand the influence of treatment processes on the material properties
e. be able to interact with material specialists

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.

9.6 Theme 6: Non-Destructive Testing

Learning outcomes

After completion of this study theme you must:

a. have a good overview of the different techniques of non-destructive testing.
b. understand the suitability of various NDT techniques.
c. be able to recommend relevant NDT techniques for specific objectives.

Study units for self-study

A guest lecturer will provide supplementary study material. Look at videos demonstrating various NDT techniques.

9.7 Theme 7: Gears and Gear Systems

Learning outcomes

After completion of this study theme you 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. describe 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 group assignment, the team will be expected to do a preliminary design of a gearbox as part of a transmission system of a drive train. Contact stresses and lubrication issues need to be considered as well.

9.8 Theme 8: Contact Stresses

Learning outcomes

After completion of this study theme you 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

Shigley, Chapter 3.19. as well as supplementary material provided.

Assignment for assessment

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

9.9 Theme 9: Lubrication / Tribology

Learning outcomes

After completion of this study theme you should:

a. understand the principles of tribology.
b. understand the properties of lubricants.
c. know about 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

Shigley, 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

ECSA Graduate Attributes

Extracts from Document No: E-02-PE ECSA (available on ClickUp):

General Range Statement: The competencies defined in the eleven graduate attributes may be demonstrated in a university-based, simulated workplace context. Competencies stated generically may be assessed in various engineering disciplinary or cross-disciplinary contexts.

Level Descriptor: Complex Engineering Problems:

a) require in-depth fundamental and specialized engineering knowledge, and have one or more of the characteristics:

i) are ill-posed, under-or over specified, or require identification and refinement;

ii) are high-level problems including component parts or sub-problems;

iii) are unfamiliar or involve infrequently encountered issues;

b) and their solutions have one or more of the characteristics:

i) are not obvious, require originality or analysis based on fundamentals;

ii) are outside the scope of standards and codes;

iii) require information from a variety of sources that is complex, abstract or incomplete;

iv) involve wide-ranging or conflicting issues: technical, engineering and interested or affected parties.

While all 11 Graduate Attributes (GA) are of relevance, this course must address specifically GA 8.

Be aware that you can fail this module until you comply with the outcome of GA 8.

Graduate Attribute 8: Individual, Team and Multidisciplinary Working

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

Range Statement: Multidisciplinary tasks require co-operation across at least one disciplinary boundary. Co-operating disciplines may be engineering disciplines with different fundamental bases other than that of the programme or may be outside engineering.

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 spent on homework, assignments, and preparation for tests and examinations for this 16 credit module.