UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie

SCHOOL OF ENGINEERING, THE BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

DEPARTMENT OF MECHANICAL AND AERONAUTICAL ENGINEERING

STUDY GUIDE

MACHINE DESIGN

MOW 312

Last revision by:

MJR Schoeman

March 2017

Table of Contents

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 and should therefore be approached with great eagerness.

It is the objective of this first semester course to show the student the bigger picture of the solution development process and to show how the design process systematically narrows down a problem (challenge) to the level of detail design at the piece-part's level. The design engineer needs to be aware of his responsibility to remain focused on the actual problem and to select conceptual solutions systematically, wisely and creatively on the road to the detail solution. The student needs to develop self confidence in this open ended process in which he/she needs to guide by their ability of rational reasoning and lateral thinking. The student should be stimulated to become more curious in discovering the actual causes behind effects and to become more creative to discover the best causes to achieve a desired outcome. The student should improve his/her skill of visualizing and systematically describing systems in diagram, in word and in sketch, in mathematical model and by calculation.

The student shall understand that the design engineer manages an innovative process of which much detail can be contracted to specialists. While the student will be exposed to selected specialist themes it is not the objective of this course to make him a specialist in such themes but rather to use such themes in a variety of examples of steps in the design process. It is assumed that such specialist themes are addressed in other courses and that the student will be able to apply his skill of self-study to familiarize himself with knowledge, method and procedure consolidated in handbooks, regulations, codes, computer codes and other sources of collective information.

Design is normally associated with systems, therefore this module will be considered in a framework of Systems Engineering.

2 LECTURER AND CONSULTING HOURS

	Name	Building / Office	Phone No.	Email Address
Lecturer	Mr. MJR Schoeman	Eng I, room 9-16	012 420 4745	u2906565@tuks.co.za
TA	t.b.a			
TA	t.b.a			
TA	t.b.a			

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

Consulting hours

Hours for consultation of the lecturer will be displayed on the office doors. Students may consult the lecturer only during these indicated consulting hours, or else strictly **by confirmed appointment only**. This policy also holds close to the time of tests and exams. Students are therefore encouraged to plan their work well and to work continuously throughout the semester.

The lecturer will be available after class for half an hour for ad hoc consultation (unless announced otherwise). Students are encouraged to discuss any issues first amongst each other and to organize group consultations or to raise issues in class if these are likely to be of benefit to all students.

Tutorial sessions are intended for questions and discussions arising from the work, the homework and the assignments.

Issues of quality of service should, **as soon as such become apparent**, be discussed with the **class representative (**or with the lecturer directly), 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, with the Head of Department.

3 STUDY MATERIAL AND PURCHASES

The following study material is required:

- Notes of the previous courses of Machine Design (MOW 217 and 227),
- **Shigley's Mechanical Engineering Design, 9th edition** (or later), by Richard G. Budynas; J. Keith Nisbett
- SANS code: SANS 10162-1:2011 “Part 1L: Limit-state design of hot-rolled steelwork”
- Structural Steel Design (to SANS 10162:1) by Gregg Parrott

The following books are recommended:

- **Design of Machinery, 3rd edition**, by RL Norton
- South African Steel Construction Handbook, 7th edition

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.
There will be one 3 hour tutorial session per week.

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 3 to 6 hours per week. **The student is advised to devote another 6 to 8 hours per week of own study time to this module**.

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 class as guided and are advised to participate actively in discussions during tutorial sessions.**

4.3 Tutorial sessions and assignments

The class will be divided into groups of 4 to 6 students to work on group assignments. It is important that group members can meet to work together and to have regular interactions. Assignments will be handed out as homework (group work) 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. **To make the most of these sessions the student must be prepared.** Submission deadlines for assignments will be announced on ClickUP. Students are required to bring the relevant textbooks, to the tutorial sessions.

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 group evaluation) of at least 50%. In addition, ECSA Exit level Outcome (ELO) 8 is assessed in this module. This has the implication that if a student does not meet this outcome, the student fails.

Calculation of the final mark:
The final mark is calculated as follows:
Semester mark: 50%

Examination mark: 50%

Calculation of the semester mark:
The semester mark is compiled as follows:
Semester tests: 60%
Class tests: 10%
Assignments: 30%

For admission to the exam all these conditions must be met:

- A semester mark of at least 40%
- A minimum of 50% for the average of the assignments (after group evaluation)
- An average of more than 6 out of 12 ticks in the ECSA ELO 8 assessment matrix in the Appendix for all group work.

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).

Class tests: A few class tests will be written during some of the tutorial sessions on homework which has been assigned for self-study

Assignments: The mark for assignments will contribute to the semester mark in proportion to their complexity.

6 GENERAL

Although group work will be encouraged students are required to 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. Team evaluations will be done at the end of the semester. These evaluations will be used to up- or down-grade the individual score for assignments if necessary. Note, team members who did not contribute to the assignments can thus be failed by their peers and may fail to be admitted to the final examination!

7 MODULE STRUCTURE

This module will be treated within a framework of system engineering. The module frame addresses the design philosophy and design process in the context of System Engineering and 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 the themes not treated in this study material.

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 area, CDIO, new curriculum and assessment of cognitive levels. **It is expected that you are familiar with the content of the Departmental Study Guide**. It is available in English and Afrikaans on the Department's website.

English
http://www.up.ac.za/media/shared/120/Noticeboard/2017/departmental-studyguide-eng-2017.zp107056.pdf

Afrikaans
http://www.up.ac.za/media/shared/120/Noticeboard/2017/departementele-studiegids-afr-2017.zp107058.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 MODULE STRUCTURE

The module structure is as follows:

Study Theme:	Contact Sessions:	Notional hours:
Framework – Systems Engineering	6	27
Study Theme 1 – Human Factor and Ergonomics	3	14
Study Theme 2 – Pressure Vessels	3	14
Study Theme 3 – Structural Design	6	27
Study Theme 4 – Welding and Bonding	3	14
Study Theme 5 – Heat treatment of Materials	1	5
Study Theme 6 – Non-destructive testing	1	4
Study Theme 7 – Gears and Gear Systems	6	27
Study Theme 8 – Contact Stresses	3	14
Study Theme 9 – Lubrication/Tribology	3	14
Total	**35**	**160**

10 STUDY THEMES

The following lists the themes which will receive special emphasis during this course.

10.1 Module Framework: SYSTEMS ENGINEERING

10.1.1 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 specialist in their relevant fields. The student 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. know the typical steps of the design process in the context of the organizational environment.
c. know the basic building blocks of engineering systems.
d. understand the importance and the role of the systems analysis and the functional analysis.
e. be comfortable to compile a functional analysis at various levels of a system.

10.1.2 Study units for self-study

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

10.1.3 Assignment for assessment

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

10.2 Study Theme 1: HUMAN FACTOR AND ERGONOMICS

10.2.1 Learning outcomes

After the completion of this study theme the student should:

a. understand important physiological factors which influence human performance.
b. know about the important safety and health issues which need to be respected at all times during any design.
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.

10.2.2 Study units for self-study

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

10.2.3 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 force limits and the available work for the operation of a system activated by a human user.

10.3 Study Theme 2: PRESSURE VESSELS

10.3.1 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.

10.3.2 Study units for self-study

Study and understand the notes provided. This includes 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.

10.3.3 Assignments for assessment

As a team assignment the theme of pressure vessels will be used in an example in a feasibility study and a concept evaluation. This will require the basic strength calculations and interpretation of the regulations.

10.4 Study Theme 3: STRUCTURAL DESIGN

10.4.1 Learning outcomes

As a subsection of structural design some attention will be given to structural steel design as described in the prescribed handbook and its associated code. This serves as an example to illustrate that the process of structural design has in some fields been consolidated into guidelines which can be applied without the deeper understanding of the first principles. However, since the university engineering student is expected to understand and apply the first principles approach the student is not expected to become a practiced user of the code. The student should however take note of the modern trend in structural steel design, which leans towards limit state design rather than stress based design. Most of the structural steel design codes are based on limit state design. In

South Africa, SANS 10162 is often used for the design of steel structures when a fast solution takes preference over an optimized solution.

The purpose of this study theme is:

a. to introduce the concept of limit state design as an alternative to stress based design.
b. to introduce the method of code based design for use in structural steel design.
c. to show how first principles and experience can be consolidated into codes to simplify practical design of steel structures.
d. to understand the difference between serviceability- and ultimate limit states.
e. to understand the difference between load factors, safety factors and resistance factors.
f. to understand the difference between 'dead loads' and ' live loads'.

10.4.2 Study units for self-study

Study the prescribed book: 'Structural Steel Design' in conjunction with code: SANS 10162.

10.4.3 Assignments for assessment

As a team assignment the theme of structural design will be used in an example in a feasibility study and a concept evaluation. 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.

10.5 Study Theme 4: WELDING AND BONDING

10.5.1 Learning outcomes

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

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

10.5.2 Study units for self-study

Study Shigley chapter 9 and Parrot chapter 3.2

10.5.3 Assignments for assessment

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

10.6 Study Theme 5: HEAT TREATMENT OF MATERIALS

10.6.1 Learning outcomes

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

a. select an appropriate material.
b. specify the necessary heat treatment for annealing, quenching, tempering and case hardening.
c. understand the pros and cons of different heat treatment processes that can be used in the manufacturing processes.

10.6.2 Study units for self-study

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

10.6.3 Assignments for assessment

Included in Assignment 10.5.3

10.7 Study Theme 6: NON-DESTRUCTIVE TESTING

10.7.1 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 processes for purposes of continued operational quality assessment.

10.7.2 Study units for self-study

A guest lecturer will be providing supplementary study material.

10.7.3 Assignment for assessment

Included in Assignment 10.5.3

10.8 Study Theme 7: GEARS AND GEAR SYSTEMS

10.8.1 Learning outcomes

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

a. choose suitable gear systems appropriately.
b. analyse and design different gear systems.
c. design an appropriate gear system for a specified application.
d. design a gear set for strength and fatigue.

10.8.2 Study units for self-study

Revision of the material of gears covered in previous courses. Study and understand the contents of Shigley, Chapters 13, 14 and 15.

10.8.3 Assignments for assessment

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

10.9 Study Theme 8: CONTACT STRESSES

10.9.1 Learning outcomes

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

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

10.9.2 Study units for self-study

Study and understand the contents in Shigley on contact stresses (Chapter 3.19).

10.9.3 Assignment for assessment

Included in Assignment 10.8.3

10.10 Study Theme 9: LUBRICATION / TRIBOLOGY

10.10.1 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.

10.10.2 Study units for self-study

Study and understand the contents in Shigley about lubrication (Chapter 12 and other subsections).

10.10.3 Assignment for assessment

Included in Assignment 10.8.3

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:
BSc(Eng)/BEng/BIng Qualification PE-61 Rev 2 Page 7 of 11

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.