Module Title: **3B3 Mechanics of Solids**

Code: **ME3B3**

Level: **Junior Sophister**

Credits: **5**

Lecturer(s): **Assistant Prof. Tim Persoons (tim.persoons@tcd.ie)**
Assistant Prof. Michael Monaghan (monaghmi@tcd.ie)

Module Organisation

The module runs for 12 weeks of the academic year and comprises three lectures per week. One tutorial is given every week in groups of up to 20 students. One 3-hour laboratory session is given in groups of up to 5 students. Total contact time is 47 hours.

Semester	Start Week	End Week	Lectures		Tutorials		Laboratory
			per week	total	per week	total	total
2	1	12	3 h	33 h	1 h	11 h	1x 3h
Total Contact Time: 47 h							

Two individual assignments will be due during the module of the module, (1) on an individual micro-project (estimated effort: 30 h) and (2) a report on the lab experiments (estimated effort: 10 h). The estimated effort for self-study is 60 h.

Module Description

This is a module on the fundamentals of stress analysis which is a central subject in the mechanical engineering discipline. Students learn how to determine the stresses and strains in typical mechanical components, such as beams and pressure vessels, as well as in structures under combined loads of torsion and bending. Buckling and stability of structures is also introduced and experimental strain measurement is covered by lectures and a laboratory session. In addition to the development of modelling skills, the analysis also relies on mathematical techniques commonly used in advanced engineering such as solution of differential equations, Laplace transform and eigenvalue analysis. The subject introduces computing as a tool for the solution of more complex structural problems. However, the emphasis is on acquiring theoretical and analytical skills as well as gaining physical insight in how to represent real-life complex structures and loads as a combination of simplified basic cases.

This module completes the essential requirements of a mechanical engineer in the solids and structural mechanics area. It builds on earlier introductory (fundamental and applied) modules in mechanics, mathematics and numerical methods. Its main aim is to provide the theoretical basis for more advanced modules in solid mechanics, fluid mechanics, vibration and bioengineering. The module aims to build up the essential skills and confidence for becoming an expert user of commercial software packages relying on finite element analysis, which will be used extensively in project work after the third year.

Learning Outcomes

On successful completion of this module, the student will be able to:

1. Comprehend the fundamentals of stress/strain analysis and apply them with confidence to the calculation of loads and deformations in simple structures;
2. Recognize the relationships between commonly used material properties, and recall their value for typical materials used in mechanical engineering structures (e.g., steel, aluminum);
3. Analyze and examine a physical problem and reformulate it in a frame (e.g., a differential equation or eigenvalue problem) for which he/she has developed the mathematical tools;
4. Develop free-body diagrams which form the basis of many formulations in mechanics, to separate more complex loaded structures into combinations of elemental sections;
5. Critically evaluate and judge the validity of a method of analysis in a solid mechanics problem in terms of its assumptions and simplifications.

Module Content

- ***Relationships between Stress and Strain***
  An understanding of axial and shearing stress and strain and the relationships between them are developed.
- ***Two Dimensional Stress Analysis***
  Multi-axial stress stress/strain analysis is introduced and the concept of principal loads and simple failure mechanisms. The use of traditional Mohr circle and computer based tensor methods are also introduced. The application to strain gauge methods is then developed.
- ***Energy Methods***
  Energy approaches based on the concept of virtual work and the theorems of Castigliano are now developed and shown to be often a useful alternative to direct force equilibrium modelling.
- ***Torsion of circular and general Thin Sections***
  Torsional deflection analysis of circular sections is introduced in the context of a special case of shear loading. A variety of problems in shaft design are considered with an extension of the analysis to tapered sections and non-circular thin walled sections where an energy based method is developed.
- ***Advanced Beam Theory***
  Beam theory developed from fundamental equations to study a variety of loadings and solution approaches. Direct integration methods are used with appropriate development of the mathematics of discontinuous functions. Various strategies are developed to analyse statically indeterminate problems and finally analysis of shear stress distributions are introduced.
- ***Buckling of Struts***
  Beam theory is used to derive governing differential equations of buckling which are solved using Laplace techniques developed in earlier modules. Various end loadings, eccentricity and some simple structures are analysed.
- ***Analysis of Composites***

Various beam problems using composite material cross-sections are considered and design constraints for these types of problems are explored.

Lab/Assignments

Strain Gauges: In this three-hour laboratory session, the performance of a strain gauge rosette sensor mounted on a simply supported beam loaded under bending is studied experimentally. This allows the student to draw directly from beam theory, strain gauge and experimental techniques. A report will be prepared on the experiments carried out and the subsequent data analysis, which accounts for 10% of the total marks of the module.

Micro-Project Assignment: An individual micro-project will be carried out by each student on a topic of their own choice related to solid mechanics. The goal is to analyse a real-life problem involving mechanical loads, make justified simplifications to carry out an analysis (without the use of computer simulation), calculate relevant loads and deformations or failure criteria, possibly suggest alternative designs, and present the results in a condensed and clear manner. The report will be a one-page electronic poster format, to be submitted before the end of the teaching term. A list of example topics will be provided. The micro-project will be evaluated on scientific/technical merit as well as creativity of the chosen problem and innovative nature of the solution.

Teaching Strategies

Lectures: The teaching strategy follows a single well established text book. This subject has been well developed for teaching at this level so student accessibility and consistency of notation is easily established.

Tutorials: Tutorials follow a series of question sheets, with problems similar to exam questions. The solutions for these are available online and are released gradually as the module progresses. The tutorials are given to class groupings and are informal. Tutorials are attended by teaching assistants and occasionally by the lecturers, to provide formative feedback (e.g., on the micro-project work). No assessment of tutorial performance is noted.

Laboratory Session: Carried out in a small group of up to 5 students, the objectives of this lab session are to learn how to carry out measurements using strain gauge sensors and modern computer-based data acquisition equipment, to determine the surface stress on the beam and evaluate the Poisson's ratio of the material, and compare the findings against theoretical formula using the beam bending equations.

Assessment Modes

The final grade for this module is determined as the sum of the marks on a two-hour written examination, an individual micro-project assignment and a laboratory experiment assignment:

Assessment component	Contribution to total mark
Exam[1]	70%
Lab experiment assignment[2]	10%
Micro-project assignment[3]	20%

[1] The exam is a two-hour written closed-book examination. Each question covers multiple aspects of the module, and is typically split into different parts, testing the student's basic understanding, analytical and interpretative skills.

[2] The lab report is due 2 weeks after completing the lab session. The lab demonstrator takes a record of attendance during the lab session and marks the report on completeness, technical accuracy and clarity.

[3] The micro-project assignment consists of a one-page electronic poster, to be submitted before the end of the teaching term. It is marked on creativity and innovativeness of the selected problem and methods (1/3 of mark), scientific/technical merit (1/3), and quality and clarity of the poster (1/3).

Recommended Texts

James M. Gere, *Mechanics of Materials*, (any edition) (e.g., Hamilton 620.11 L21*7)

Laboratories

- Strain Gauges Lab

Prerequisites

- 1E7 Mechanics (or equivalent)
- 2E4 Solids and Structures (or equivalent)