

# 1 Introduction

This brief chapter introduces the subject of Solid Mechanics and the contents of this book



# 1.1 What is Solid Mechanics?

Solid mechanics is the study of the deformation and motion of solid materials under the action of forces. It is one of the fundamental applied engineering sciences, in the sense that it is used to describe, explain and predict many of the physical phenomena around us.

Here are some of the wide-ranging questions which solid mechanics tries to answer:

When will this cliff collapse?



1



How does the heart contract and expand as it is pumped?

2



When will these gears wear out?

3

How long will a tuning fork vibrate for?



How will the San Andreas fault in California progress? How will the ground move during an earthquake?



4



how do you build a bridge which will not collapse?

5

why does nature use the materials it does?



6

Knee

Solid mechanics is a vast subject. One reason for this is the wide range of materials which falls under its ambit: steel, wood, foam, plastic, foodstuffs, textiles, concrete, biological materials, and so on. Another reason is the wide range of applications in which these materials occur. For example, the hot metal being slowly forged during the manufacture of an aircraft component will behave very differently to the metal of an automobile which crashes into a wall at high speed on a cold day.

Here are some examples of Solid Mechanics of the cold, hot, slow and fast ...



7

8

how did this Antarctic ice fracture?  
what materials can withstand extreme heat?

how much will this glacier move in one year?  
what damage will occur during a car crash?

Here are some examples of Solid Mechanics of the small, large, fragile and strong ...



9

what affects the quality of paper?  
(shown are fibers 0.02mm thick)  
how will a ship withstand wave slamming?

how strong is an eggshell and what prevents it from cracking?  
how thick should a dam be to withstand the water pressure?

### 1.1.1 Aspects of Solid Mechanics

The theory of Solid Mechanics starts with the **rigid body**, an ideal material in which the distance between any two particles remains fixed, a good approximation in some applications. Rigid body mechanics is usually subdivided into

- **statics**, the mechanics of materials and structures at rest, for example of a cable-stayed bridge
- **dynamics**, the study of bodies which are changing speed, for example of an accelerating and decelerating elevator

Following on from statics and dynamics usually comes the topic of **Mechanics of Materials** (or **Strength of Materials**). This is the study of some elementary but very relevant deformable materials and structures, for example beams and pressure vessels. **Elasticity theory** is used, in which a material is assumed to undergo *small* deformations when loaded and, when unloaded, *returns to its original shape*. The theory well approximates the behaviour of most real solid materials at low loads, and the behaviour of the “engineering materials”, for example steel and concrete, right up to fairly high loads.

More advanced theories of deformable solid materials include

- **plasticity theory**, which is used to model the behaviour of materials which undergo *permanent* deformations, which means pretty much anything loaded high enough
- **viscoelasticity theory**, which models well materials which exhibit many “fluid-like” properties, for example plastics, skin, wood and foam
- **viscoplasticity theory**, which is a combination of viscoelasticity and plasticity, and is good for materials like mud and gels.

Some other topics embraced by Solid Mechanics, are

- **rods, beams, shells and membranes**, the study of material components which can be approximated by various model geometries, such as “very thin”
- **vibrations of solids and structures**, where particles vibrate about some equilibrium position, giving rise to vibration and wave propagation
- **composite materials**, the study of components made up of more than one material, for example fibre-glass reinforced plastics
- **geomechanics**, the study of materials such as rock, soil and ice
- **contact mechanics**, the study of materials in contact, for example a set of gears
- **fracture and damage mechanics**, the mechanics of crack-growth and damage in materials
- **stability of structures**, the study of whether structures have the ability to return to some equilibrium position after being disturbed, or perhaps catastrophically fail
- **large deformation mechanics**, the study of materials such as rubber and muscle tissue, which stretch fairly easily
- **biomechanics**, the study of biological materials, such as bone and heart tissue
- **variational formulations and computational mechanics**, the study of the numerical (approximate) solution of the mathematical equations which arise in the various branches of solid mechanics, including the Finite Element Method
- **dynamical systems and chaos**, the study of mechanical systems which are highly sensitive to their initial position
- **experimental mechanics**, the design and analysis of experimental procedures for determining the behaviour of materials and structures
- **thermomechanics**, the analysis of materials using a formulation based on the principles of thermodynamics



## Images used:

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## 1.2 What is in this Book?

The aim of this book is to cover the essential concepts involved in solid mechanics, and the basic material models. It is primarily aimed at the Engineering or Science undergraduate student who has, perhaps, though not necessarily, completed some introductory courses on mechanics and strength of materials. Apart from giving a student a good grounding in the fundamentals, it should act as a stepping stone for further study in the field of Solid Mechanics, Continuum Mechanics, or any related field. The philosophy adopted is as follows:

- The mathematics is kept at a fairly low level; in particular, there are few differential equations, very little partial differentiation and there is no tensor mathematics
- The critical concepts – the ones which make what follows intelligible – are highlighted
- The physics involved, and not just the theory, is given attention
- A wide range of material models are considered, not just the standard Linear Elasticity

The outline of the book is as follows: Chapter 2 covers the essential material from a typical introductory course on mechanics; it serves as a brief review for those who have seen the material before, and serves as an introduction for those who are new to the subject. Chapters 3-8 cover much of the material typical of that included in a Strength of Materials or Mechanics of Materials course, and include the elementary beam theory and energy methods. The latter part of the book, Chapters 10-12 cover more advanced material models, namely viscoelasticity, plasticity and viscoplasticity.

