

Chapter 1: Engineering Mechanics

Technical & Professional Knowledge for NICL AO (Scale I) 2026, Risk Engineer: Phase II (Main) exam

Contents

Chapter opener.....	2
1.1 Introduction to mechanics.....	5
1.2 Force systems and resultant.....	8
1.3 Moments, couples and Varignon's theorem.....	11
1.4 Equilibrium.....	14
1.5 Friction.....	19
1.6 Centroid and centre of gravity.....	23
1.7 Moment of inertia.....	27
1.8 Plane trusses.....	31
1.9 Beams: shear force and bending moment.....	33
1.10 Simple stress, strain and material properties.....	41
1.11 Simple lifting machines.....	47
1.12 Kinematics.....	51
1.13 Kinetics.....	55
Revision kit.....	59
Practice set: 100 questions.....	64
Answer key.....	82

Independent study material; not affiliated with or endorsed by National Insurance Company Limited.

Chapter opener

What this chapter covers

Engineering mechanics is the study of how forces act on bodies: whether a structure stays put, how a machine multiplies an effort, how a beam bends, how a material stretches, and how things move. It is the foundation of every other engineering subject, and it is the first topic a Risk Engineer uses when judging whether a building, a crane or a pressure part is safe.

The chapter has thirteen units. Units 1.1–1.9 cover statics (forces, moments, equilibrium, friction, centroids, moments of inertia, trusses and beams), Unit 1.10 covers the basics of strength of materials, Unit 1.11 covers simple machines, and Units 1.12–1.13 cover motion.

Each unit has a **core** part, which every reader should learn, and, where useful, a shaded **Optional recall** box of standard results you may meet elsewhere. The 100 practice questions at the end test only the core. The Optional boxes can be left for a second reading.

Learning objectives

After this chapter, you should be able to:

1. Use SI units and the dimensions of mechanical quantities.
2. Find the resultant of a force system and apply the conditions of equilibrium to a planar rigid body, including Lami's theorem.
3. Distinguish static, limiting and kinetic friction, and link μ , the angle of friction and the angle of repose.
4. Locate the centroids of standard plane shapes and composite areas; recall the area moments of inertia of rectangles and circles and apply the two axis theorems.
5. Recognise an ideal truss and its member-count condition; classify beams and recall standard shear-force and bending-moment results with their loading cases.
6. Define stress, strain and the elastic constants; read an engineering stress–strain curve; distinguish resilience, toughness and other material properties.
7. Work with the mechanical advantage, velocity ratio and efficiency of simple machines, and classify levers.
8. Apply the constant-acceleration equations, projectile relations, and the work–energy and impulse–momentum principles under their stated assumptions.

Topic map

Unit	What you will learn	Practice questions
1.1 Introduction to mechanics	Branches, idealisations, scalars and vectors, units and dimensions	Q1–Q5
1.2 Force systems and resultant	Types of force systems, parallelogram law, resolution, equilibrant	Q6–Q11, Q91
1.3 Moments and couples	Moment of a force, Varignon's theorem, couples, moving a force	Q12–Q16

Unit	What you will learn	Practice questions
1.4 Equilibrium	Equilibrium equations, free body diagrams, supports, Lami's theorem	Q17–Q23, Q92
1.5 Friction	Static, limiting and kinetic friction, angle of repose, rolling	Q24–Q30, Q94
1.6 Centroid and centre of gravity	Standard shapes, symmetry, composite areas	Q31–Q35
1.7 Moment of inertia	Second moment of area, radius of gyration, axis theorems	Q36–Q41, Q95
1.8 Plane trusses	Ideal trusses, member count, joints and sections, zero-force members	Q42–Q45
1.9 Beams: shear force and bending moment	Beam and load types, SF and BM diagrams, standard results	Q46–Q54, Q93, Q96
1.10 Stress, strain and material properties	Stress, strain, elastic constants, stress–strain curve, properties	Q55–Q70, Q97
1.11 Simple lifting machines	MA, VR, efficiency, reversibility, levers	Q71–Q74
1.12 Kinematics	Equations of motion, graphs, projectiles, circular motion	Q75–Q81, Q98
1.13 Kinetics	Newton's laws, lifts, work, energy, power, impulse, collisions	Q82–Q90, Q99, Q100

Exam context

- **The section:** 50 questions, 50 marks, 35 minutes. That is an *average* of 42 seconds a question. Quick recall questions buy time for the occasional calculation.
- **Marking:** +1 for a correct answer, –0.25 for a wrong one, 0 if you leave it blank.
- **No calculators:** the practice numericals (Q91–Q100) and the worked examples use numbers you can handle mentally; where an example quotes an angle such as 53° , it is for illustration, not something you must work out in the exam.

Source: the NICL recruitment notice dated 07/10/2026, as transcribed for this book.

Should you guess?

If p is your honest chance of being right, the expected mark from answering is

$$\text{Expected mark} = p - 0.25(1 - p) = 1.25p - 0.25$$

- The break-even point is $p = 20\%$, the chance of a blind pick among five options. A blind guess is worth zero *on average*, though any single guess gains or loses.
- Reliable elimination raises p . If the options you rule out really are wrong and the rest are equally likely: one option out gives +0.063 per guess, two out gives +0.167, three out gives +0.375.
- Ruling out the right answer by mistake reverses the gain. Answer the questions you are sure of first, and don't spend long on guesses.

How to use this chapter

1. Read a unit, then study its figures and worked examples.
2. Attempt that unit's practice questions and check them against the answer key.
3. Before attempting all 100 questions in one sitting, revise with the revision kit at the end of the theory.
4. Leave the Optional recall boxes for a second reading.

Conventions used in this chapter

- **Units:** SI throughout. Stresses are in N/mm^2 (= MPa) and elastic moduli in GPa or N/mm^2 .
- **Gravity:** $g = 9.81 \text{ m/s}^2$ in the theory. Every practice numerical that needs g states $g = 10 \text{ m/s}^2$, to keep the arithmetic mental.
- **Signs:** forces are positive to the right and upward; moments are positive anticlockwise; tension is positive. The beam sign convention is set out in 1.9.2.
- **Symbols:** N is the normal reaction (many textbooks write R); μ_s and μ_k are the coefficients of static and kinetic friction; R is a resultant force; W is a point load or a weight, never work; I is an area moment of inertia and I_m a mass moment of inertia; ν is Poisson's ratio (some textbooks write μ or $1/m$).
- **Abbreviations:** FBD free body diagram; SSB simply supported beam; UDL uniformly distributed load; UVL uniformly varying load; SF shear force; BM bending moment; SFD and BMD shear-force and bending-moment diagrams; MI moment of inertia; CG centre of gravity; MA mechanical advantage; VR velocity ratio; FoS factor of safety; KE kinetic energy; PE potential energy.

1.1 Introduction to mechanics

In a nutshell. Mechanics studies how forces affect bodies, at rest and in motion. Engineers work with simple models of real bodies, a handful of laws, and a consistent system of units.

1.1.1 What mechanics studies

Mechanics is the branch of science that deals with forces and their effects on bodies. It splits into three parts according to the kind of body studied:

- **Rigid-body mechanics** treats bodies as if they did not deform. It has two branches:
 - **Statics** deals with bodies at rest or in equilibrium, that is, with no acceleration.
 - **Dynamics** deals with bodies in motion and how forces affect that motion. It has two parts: **kinematics** describes motion (displacement, velocity, acceleration) without asking what causes it; **kinetics** relates motion to the forces that cause or change it.
- **Deformable-body mechanics**, usually called **strength of materials**, studies how bodies stretch, compress, twist and bend under load (Unit 1.10).
- **Fluid mechanics** studies liquids and gases. Fluid statics is covered in a later chapter of this book.

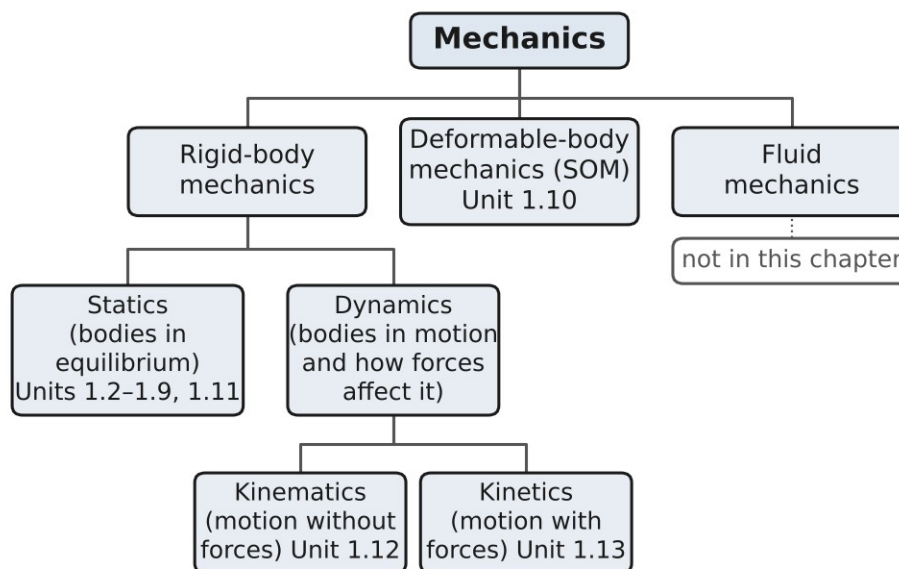


Figure 1.1. The branches of mechanics. A tree diagram: mechanics divides into rigid-body, deformable-body and fluid mechanics; rigid-body mechanics divides into statics and dynamics; dynamics divides into kinematics and kinetics.

1.1.2 Idealisations and basic laws

Real bodies are complicated, so mechanics works with simplified models:

- A **particle** has mass but negligible size, so all of its mass is treated as acting at one point. A car on a 500 km route can be treated as a particle.
- A **rigid body** is one in which the distance between any two points stays the same under load. Real bodies deform slightly, but when the deformation is tiny compared with the body's size, it can be ignored for finding the forces.
- A **continuum** treats matter as continuous, ignoring its atomic structure.