



**14th Edition**

# **ENGINEERING MECHANICS STATICS AND DYNAMICS**



**A. K. TAYAL**

**UMESH**

# ENGINEERING MECHANICS: STATICS AND DYNAMICS

**Dr. A.K. Tayal**

# ENGINEERING MECHANICS STATICS AND DYNAMICS

**A.K. Tayal**

Ph. D.

Formerly Professor

Department of Mechanical Engineering  
Delhi College of Engineering (Now Deemed University)  
**Delhi**

*Compiled by*

**Deeksha Tayal**



**UMESH PUBLICATIONS**

Publishers of Engineering and Computer Books

4230/1, Ansari Road, Daryaganj, Delhi-110 002

Phones: (O) 32957898, 43028013

**Engineering Mechanics : Statics and Dynamics**

**A.K. Tayal**

*Published by:*

**UMESH PUBLICATIONS**

4230/1, Ansari Road, Daryaganj, Delhi-110 002

Phone : 32957898, 43028013

© **Publishers**

**First Edition : 1989**

**Tenth Edition : 1999**

**Eleventh Edition : 2000**

**Thirteenth Edition : 2005**

**Fourteenth Edition : 2011 (Revised and Enlarged)**

*All rights reserved, No part of this publication may be reproduced, translated or transmitted (except for review or criticism), without the written permission of the publishers.*

**ISBN: 978-93-80117-38-6**

**Price : Rs 330.00**

*Laser Typeset by:*

**SARA Assignments**, Shahdara, Delhi-110 032.

*Printed at:*

**Narula Printers**, Navin Shahdara, Delhi-110 032.

## *Preface to the Fourteenth Edition*

---

It gives me a great pleasure to present the Fourteenth Edition of this book on Engineering Mechanics. I express my gratitude for the wide acceptability of the book by the academics as well as student community and it gives me deep sense of satisfaction. In this new edition, a new chapter on 'Shear Force and Bending Moment' has been added. This topic is included to meet the current requirements of some universities.

I again, request for the suggestions and comments for the improvement of the book.

Delhi  
January, 2011

**Dr. A.K. TAYAL**

## *Preface to the First Edition*

---

Mechanics is essentially a deductive science based on a few fundamental principles and has vectorial character. This book has been written with a view to emphasize the vectorial character of mechanics in such a manner so that the material presented may not require any previous knowledge of mathematics beyond elementary calculus. For this reason, products and derivatives of vectors are not used. A chapter on the 'Review of Vectors and Forces in Space', however, has been included as an appendix to introduce the vector approach of the subject. This chapter can be covered before going on the mechanics of coplanar system of forces.

It is a well recognised fact that the teaching of the first course in a subject should be based on a text book. A systematic, consistent and clear presentation of concepts through explanatory notes and figures and worked out problems are the main requirements of a text book. This book has been written to meet such requirements. Merely stating the principles and explaining the concepts is not enough; these are to be identified as applicable to the various problems which may appear to be strangely different. With this objective, a large number of worked-out problems have been included in this book. In the most worked-out problems, free-body diagrams have been separately drawn with the coordinate axes shown. The equations of equilibrium or of motion, as applicable, have been indicated. Inertia forces have also been clearly identified in a problem. Alternative methods of solution to a number of problems have given or indicated to explain the comparative merits of the concepts and solution procedures involved. In fact, skill through repetition may be as much true here as in occult sciences.

I am grateful to many of my faculty colleagues and numerous students at Delhi College of Engineering, Delhi (now Deemed University) who have contributed significantly by way of constructive and useful discussions. The patience of the family members and the encouragement by friends is gratefully acknowledged.

I am also thankful to the publishers who have taken keen interest throughout the preparation of the book.

Despite my best efforts, it is possible that some unintentional errors may have escaped my attention. I would gratefully acknowledge if any of these is pointed out. Also, any suggestions and comments for further improvement of the book would be gratefully received and acknowledged.

Delhi

**A. K. TAYAL**

# Contents

*Preface to the Fourteenth Edition*  
*Preface*

*vi*  
*vii*

## 1. INTRODUCTION

1–6

- 1.1 Engineering Mechanics 1
- 1.2 Idealization of Bodies 1
- 1.3 Basic Concepts 1
- 1.4 Fundamental Principles 2
- 1.5 Systems of Units 4

## 2. CONCURRENT FORCES IN A PLANE

7–58

- 2.1 Force 7
- 2.2 Scalar and Vector 7
- 2.3 Addition of Two forces: Parallelogram Law 8
- 2.4 Concept of the Resultant of Several Forces 11
- 2.5 Resultant of Several Concurrent Coplanar Forces: Polygon Law 12
- 2.6 Resolution of a Force into Components 13
- 2.7 Resultant of a Several Concurrent Coplanar Forces by  
Summing Rectangular Components (Method of Projections) 15
- 2.8 Equations of Equilibrium for a System of Concurrent Forces in a Plane 18
- 2.9 Constraint, Action and Reaction 19
- 2.10 Types of Supports and Support Reactions 20
- 2.11 Free-Body Diagram 21
- 2.12 (a) Equilibrium of a Body Subjected to Two Forces (Two Force Body) 24
- 2.12 (b) Equilibrium of a Body Subjected to Three Forces 27
- Problems* 42
- 2.13 Moment of a Force 47
- 2.14 Theorem of Varignon 47
- 2.15 Equations of Equilibrium 49
- Problems* 56

**3. PARALLEL FORCES IN A PLANE** **59–81**

- 3.1 Parallel Forces 59
- 3.2 Resultant of Two Parallel Forces Acting in the Same Direction 60
- 3.3 Resultant of Two Unequal Parallel Forces Acting in Opposite Directions 61
- 3.4 Two Equal Parallel Forces Acting in Opposite Directions; Couple 61
- 3.5 The Resolution of a Force into a Force and a Couple 62
- 3.6 Equivalent System of Forces 62
- 3.7 General Case of Parallel Forces in a Plane 63
  - Problems* 71
- 3.8 Distributed Forces in a Plane 73
- 3.9 Hydrostatic Pressure: Forces on Submerged Surfaces 75
  - Problems* 80

**4. CENTROID, CENTRE OF MASS AND CENTRE OF GRAVITY** **82–107**

- 4.1 Introduction 82
- 4.2 Centre of Gravity of a Body: Determination by the Method of Moments 82
- 4.3 Concept of Centroid 84
- 4.4 Centroid Two Dimensional Body 85
- 4.5 Determination of Centroid and Centre of Gravity: Integration Method 86
- 4.6 Centroid of a Composite Plane Figure 88
- 4.7 Theorems of Pappus and Guldinus 103
  - Problems* 104

**5. GENERAL CASE OF FORCES IN A PLANE** **108–121**

- 5.1 General Case of Forces Acting in a Plane: Equations of Equilibrium 108
  - Problems* 118

**6. FRICTION** **122–147**

- 6.1 Introduction 122
- 6.2 Dry Friction 122
- 6.3 Laws of Dry Friction 123
- 6.4 Rolling Resistance 125
- 6.5 Force of Friction on a Wheel 125
  - Problems* 142

**7. APPLICATION OF FRICTION** **148–174**

- 7.1 Belt and Rope Drives 148
- 7.2 Types of Belt Drives 149

- 7.3 Belt Friction: Ratio of Tensions 154
- 7.4 Centrifugal Tension 156
- 7.5 Initial Tension in the Belt 158
- 7.6 Power Transmitted by Belts 158
- 7.7 Friction in a Square Threaded Screw 166
- 7.8 Disc and Bearing Friction 170
- Problems* 173

## 8. SIMPLE LIFTING MACHINES

175–192

- 8.1 Introduction 175
- 8.2 Simple Machines and Definitions 175
- 8.3 Ideal Machine and Frictional Losses 176
- 8.4 Simple Machine : Performance 177
- 8.5 Reversibility of Machines and Self-locking Machines 178
- 8.6 Pulleys and System of Pulleys 181
- 8.7 Wheel and Axle 185
- 8.8 Differential Wheel and Axle 186
- 8.9 Differential Pulley Block 187
- 8.10 Worm and Worm Wheel 188
- 8.11 Simple Screw Jack 189
- 8.12 Single Purchase Winch Crab 190
- Problems* 192

## 9. ANALYSIS OF PLANE TRUSSES AND FRAMES

193–234

- 9.1 Engineering Structures 193
- 9.2 Rigid or Perfect Truss 194
- 9.3 Truss : Determination of Axial Forces in the Members 195
  - 9.3.1 The Method of Joints 195
  - 9.3.2 The Method of Sections 200
- Problems* 216
- 9.4 Frames 220
  - 9.4.1 Method of Analysis 220
  - 9.4.2 Method of Analysis: Example 221
- Problems* 232

## 10. UNIFORM FLEXIBLE SUSPENSION CABLES

235–254

- 10.1 Cables and Loading 235
- 10.2 Cable Subjected to Concentrated Loads 235

- 10.3 Cable Uniformly Loaded Per Unit Horizontal Distance (Parabolic Cable) 242  
10.4 Cable Uniformly Loaded Per Unit Length Along the Cable Itself  
(Catenary Cable) 250  
*Problems* 254

## 11. GRAPHICAL ANALYSIS: COPLANAR FORCES AND TRUSSES

255–274

- 11.1 Introduction 255  
11.2 Graphical Conditions of Equilibrium 257  
11.3 Reaction at the Supports: Determination 258  
11.4 Special Problem 262  
*Problems* 263  
11.5 Graphical Method of Analysis of Simple trusses: Maxwell Diagram 265  
11.6 Method of Substitution 270  
*Problems* 273

## 12. MOMENT OF INERTIA

275–308

- 12.1 Introduction 275  
12.2 Moment of Inertia of an Area of a Plane figure with Respect to an Axis in its Plane  
(Rectangular Moments of Inertia) 275  
12.3 Polar Moment of Inertia 276  
12.4 Radius of Gyration of an Area 276  
12.5 Parallel Axis Theorem (Displacement of the Axis Parallel to Itself) 277  
12.6 Moment of Inertia of a Composite Area/Hollow Section 286  
12.7 Product of Inertia 293  
12.8 Displacement of Axes Parallel to Themselves 294  
12.9 Rotation of Axis: Principal Axes and Principal Moments of Inertia 295  
12.10 Moment of Inertia of a Mass (Rigid Body) 301  
*Problems* 304

## 13. PRINCIPLE OF VIRTUAL WORK

309–328

- 13.1 Introduction 309  
13.2 Principle of Virtual Work 310  
13.3 Application on the Principle of Virtual Work 310  
13.4 Potential Energy and Equilibrium 320  
13.5 Stability of Equilibrium: Stable, Unstable and Neutral 320  
*Problems* 326

**14. RECTILINEAR MOTION OF A PARTICLE** 329–378**Part A : Kinematics** 329

- 14.1 Introduction to Dynamics 329
- 14.2 Rectilinear Motion: Displacement, Velocity and Acceleration 330
- 14.3 Graphical Representations 331
- 14.4 Motion with Uniform Acceleration 333
- 14.5 Motion with Variable Acceleration 334
- Problems* 349

**Part B : Kinetics** 352

- 14.6 Equations of Rectilinear Motion 352
- 14.7 Equations of Dynamic Equilibrium: D'Alembert's Principle 352
- Problems* 374

**15. CURVILINEAR MOTION OF A PARTICLE** 379–427**Part A : Kinematics** 379

- 15.1 Introduction 379
- 15.2 Position Vector, Velocity and Acceleration 379
- 15.3 Components of Motion: Rectangular Components 380
- 15.4 (a) Components of Acceleration: Normal and Tangential 382
- 15.4 (b) Components of Motion : Radial and Transverse Components 390
- Problems* 397

**Part B : Kinetics** 399

- 15.5 Introduction 399
- 15.6 Equations of Motion: In Rectangular Components 399
- 15.7 Equations of Motion: In Tangential and Normal Components 400
- 15.8 Equations of Dynamic Equilibrium (D' Alembert's Principle) 401
- 15.9 Working Concepts: Curvilinear Motion 402
- 15.10 Motion of Vehicles: Level and Banked Roads 415
- Problems* 423

**16. KINETICS OF A PARTICLE : WORK AND ENERGY** 428–456

- 16.1 Introduction 428
- 16.2 Work of a Force 428
- 16.3 Energy of a Particle 433
- 16.4 Principle of Work and Energy 433
- 16.5 Work and Energy Principle for a System of Particles 436

- 16.6 Potential Energy and Conservative Forces 437
- 16.7 Principle of Conservation of Energy 438
- 16.8 Power 439
  - Problems* 453

## 17. KINETICS OF PARTICLE: IMPULSE AND MOMENTUM

457–472

- 17.1 Introduction 457
- 17.2 Principle of Impulse and Momentum 458
- 17.3 Conservation of Momentum 459
  - Problems* 466
- 17.4 Angular Momentum 467
- 17.5 Conservation of the Angular Momentum 469
  - Problems* 471

## 18. IMPACT: COLLISION OF ELASTIC BODIES

473–498

- 18.1 Introduction 473
- 18.2 Direct Central Impact 474
- 18.3 Nature of Impact and The Coefficient of Restitution 475
- 18.4 Important Cases of Impact 477
- 18.5 Loss of Kinetic Energy During Impact 479
- 18.6 Oblique Central Impact 483
- 18.7 Problems Involving Energy and Momentum 487
  - Problems* 497

## 19. RELATIVE MOTION

499–511

- 19.1 Introduction 499
- 19.2 Relative Motion between Two Particles: Velocity and Acceleration 499
- 19.3 Relative Velocity: Working Concepts 501
  - Problems* 510

## 20. MOTION OF PROJECTILE

512–532

- 20.1 Introduction 512
- 20.2 Equation of The Path: Trajectory 513
- 20.3 Expressions for Time of Flight, Height, Range and Angle of Projection 514
- 20.4 Motion of a Projectile Thrown Horizontally 515
- 20.5 Motion of a Projectile up an Inclined Plane 516
  - Problems* 531

**21. KINEMATICS OF RIGID BODY 533–558**

- 21.1 Introduction 533
- 21.2 Rotation 534
- 21.3 Linear and Angular Velocity, Linear and Angular Acceleration in Rotation 535
- 21.4 General Plane Motion 537
- 21.5 Absolute and Relative Velocity in Plane Motion 538
- 21.6 Instantaneous Centre of Rotation in Plane Motion 546
- 21.7 Location of the Instantaneous Centre 546
- Problems* 556

**22. KINETICS OF RIGID BODY: FORCE AND ACCELERATION 559–580**

- 22.1 Introduction 559
- 22.2 Plane Motion of a Rigid Body : Equations of Motion 559
- 22.3 Relation between the Translatory Motion and Rotary Motion of a Body in Plane Motion 561
- 22.4 D'Alembert's Principle in Plane Motion 576
- Problems* 576

**23. KINETICS OF RIGID BODY: WORK AND ENERGY 581–593**

- 23.1 Kinetic energy of a Rigid Body 581
- 23.2 Work of the Forces Acting on a Rigid Body 582
- 23.3 Principle of Work and Energy for a Rigid Body 583
- 23.4 Principle of Conservation of Energy 584
- Problems* 593

**24. MECHANICAL VIBRATIONS 594–618**

- 24.1 Simple Harmonic Motion 594
- 24.2 Free Vibrations (Without Damping) 598
- Problems* 608
- 24.3 Pendulum Motion 609
- Problems* 617

**25. SHEAR FORCE AND BENDING MOMENT 619–634**

- 25.1 Introduction 619
- 25.2 Types of Beams and Loading 619
- 25.3 Concept of Shear Force and Bending Moment 621
- 25.4 Definition of Shear Force and Bending Moment and Sign Convention 622

- 25.5 Shear Force and Bending Moment Diagrams for  
Standard Cases 624  
*Problems* 633

**APPENDIX****635–666****Appendix 1. Review of Vectors and Forces in Space** 635

- A-1 Definitions 635
- A-2 Components of a Force 635
- A-3 Defining a Force by its Magnitude and Two Points on its Line of Action 636
- A-4 Components of a Vector 637
- A-5 Vector Operations 641
- A-6 Angular Velocity 645
- A-7 Moment of a Force 646
- A-8 Components of a Vector and Moment about an Axis 648
- A-9 Resultant of a System of Forces in Space 651
- A-10 Equilibrium of Spatial System of Forces 653
- A-11 Types of Supports and Support Reactions  
(in Three Dimensions) 654  
*Problems* 659

**Appendix 2. Useful Formulae** 664**INDEX****667–671**

# 1

## CHAPTER

## *Introduction*

---

---

### 1.1 ENGINEERING MECHANICS

It is the science which deals with the physical state of rest or motion of bodies under the action of forces. Depending upon the nature of the body involved, it can be further divided into *mechanics of rigid bodies*, *mechanics of deformable bodies* (also called strength of materials) and the *mechanics of fluids*.

In this book, we shall deal with the mechanics of *rigid bodies*. Rigid bodies are those *bodies which do not deform under the action of applied forces*. The mechanics of rigid bodies is studied in two parts, *statics* and *dynamics*. *Statics deals with bodies at rest and dynamics with bodies in motion*.

### 1.2 IDEALIZATION OF BODIES

Matter is made up of atoms and molecules. But the real picture of matter as atoms and molecules is too complex to deal with. So to study the average measurable behaviour of bodies, we assume that *the matter is continuously distributed*. Such a description of matter is called a *continuum*. A *continuum can be rigid or deformable depending upon the assumptions we make*.

**Rigid Body.** The physical bodies deform, although slightly, under the action of loads or external forces. But in many situations this deformation is negligibly small to affect the results. So, the assumption of a rigid body shall mean that the body does not deform or the distance between any two points of the body does not change under the action of a applied force.

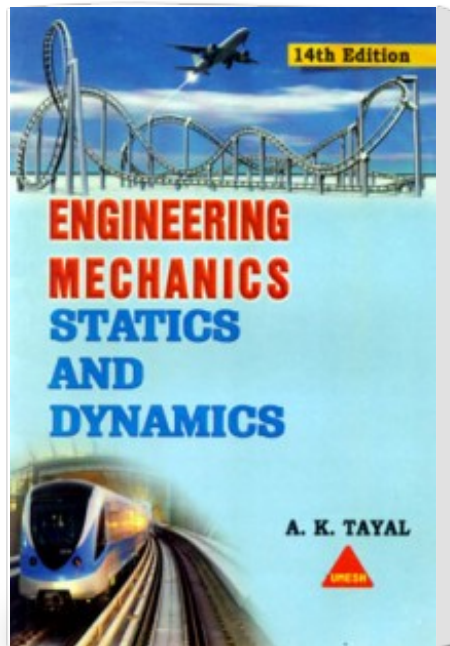
**Particle.** It is defined as an object whose mass is concentrated at a point. This assumption is made when the size of a body is negligible and is irrelevant to the description of the motion of the body.

### 1.3 BASIC CONCEPTS

The study of mechanics involves the concepts of *space*, *time*, *mass* and *force*.

- (i) Concept of space is essential to fix the position of a point. To fully define the position of a point in space we shall need to define some frame of reference and coordinate system.

# Engineering Mechanics Statics and Dynamics



Publisher : **Umesh Publications** ISBN : 9789380117386

Author : **A K Tayal**

Type the URL : <http://www.kopykitab.com/product/1275>



**Get this eBook**