

Also available as



Book

ENGINEERING MECHANICS

Statics and Dynamics

Outcome-based learning

Follows Bloom's Taxonomy



Interactive Quizzes through QR code integration

**Mc
Graw
Hill**
Education

A K Dhiman | P Dhiman | D C Kulshreshtha

About the Authors



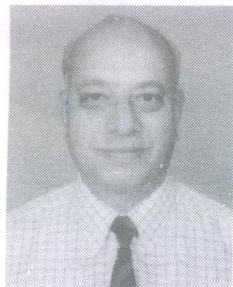
Anil Dhiman completed his BTech in Civil Engineering in 2002 from National Institute of Technology, Kurukshetra, ranked first in the state, and won two accolades—the University Gold Medal and Sh. D R Gupta memorial Gold Medal. Having worked in Larsen and Toubro for some time, he pursued MTech in Structural Engineering from NIT Kurukshetra and topped the batch with distinction.

He has academic experience of more than 11 years and is currently working as Assistant Professor in Jaypee University of Information Technology, Solan. He is pursuing doctoral research from IIT Delhi. His research interests are Blast-resistant Design of Structures, Uncertainty Qualification and Reliability, Structural Control against Wind and Earthquakes, Structural Dynamics, Smart Structures, and Structural Mechanics. He has published more than 25 research papers, and a book on *Active Control*.



Poonam Dhiman did her BTech in Civil Engineering in 2002 from National Institute of Technology, Kurukshetra, securing a position among the top five in the state. She then joined MTech in Structural Engineering at NIT Kurukshetra and secured the second position with distinction. She won the ISTE Best MTech Thesis National Award in 2005.

After working in TCE for a stint, she joined the teaching profession. She has a teaching experience of more than 10 years and is currently working as Assistant Professor in Jaypee University of Information Technology, Solan. Her research interests include Seismic Isolation of Structures, Structural Irregularities and Structural Dynamics. She has published more than 20 research papers, and a book on Seismic Isolation.



Durgesh Kulshreshtha has been working since July 2003 as Professor in Jaypee University of Information Technology, Solan. He served for more than 25 years in Delhi College of Engineering (now DTU), New Delhi. He obtained a BTech with Honours from IIT Kharagpur in 1967, and an MTech from Delhi College of Engineering, New Delhi, in 1980. For three years, he was at IIT Delhi pursuing research. He secured the second rank in the All India Merit in Engineering Services Examination, 1970, conducted by UPSC, and served the Govt. of India for five years.

He has authored/co-authored many excellent textbooks.

ENGINEERING MECHANICS

Statics and Dynamics

Anil Kumar Dhiman

Assistant Professor

Department of Civil Engineering

Jaypee University of Information Technology (JUIT)

Waknaghat, Solan, Himachal Pradesh

Poonam Dhiman

Assistant Professor

Department of Civil Engineering

Jaypee University of Information Technology (JUIT)

Waknaghat, Solan, Himachal Pradesh

Durgesh Kulshreshtha

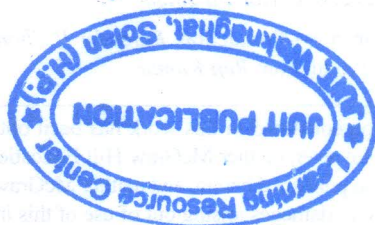
Professor

Department of Electronics and Communication Engineering

Jaypee University of Information Technology (JUIT)

Waknaghat, Solan, Himachal Pradesh

**Mc
Graw
Hill
Education**



McGraw Hill Education (India) Private Limited

NEW DELHI

McGraw Hill Education Offices

New Delhi New York St Louis San Francisco Auckland Bogotá Caracas
Kuala Lumpur Lisbon London Madrid Mexico City Milan Montreal
San Juan Santiago Singapore Sydney Tokyo Toronto



McGraw Hill Education (India) Private Limited

Published by McGraw Hill Education (India) Private Limited
P-24, Green Park Extension, New Delhi 110 016

Engineering Mechanics

Copyright © 2015 by McGraw Hill Education (India) Private Limited.

No part of this publication may be reproduced or distributed in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise or stored in a database or retrieval system without the prior written permission of the publishers. The program listings (if any) may be entered, stored and executed in a computer system, but they may not be reproduced for publication.

This edition can be exported from India only by the publishers,
McGraw Hill Education (India) Private Limited.

Print Edition:

ISBN-13: 978-93-392-1917-8

ISBN-10: 93-392-1917-1

Ebook Edition:

ISBN-13: 978-93-392-1929-1

ISBN-10: 93-392-1929-5

Managing Director: *Kaushik Bellani*

Head—Products (Higher Education and Professional): *Vibha Mahajan*

Assistant Sponsoring Editor: *Koyel Ghosh*

Senior Editorial Researcher: *Vaishali Thapliyal*

Manager—Production Systems: *Satinder S Baveja*

Assistant Manager—Editorial Services: *Sohini Mukherjee*

Assistant Manager—Production: *Anjali Razdan*

Senior Graphic Designer—Cover: *Meenu Raghav*

Senior Publishing Manager: *Shalini Jha*

Editorial Executive: *Harsha Singh*

General Manager—Production: *Rajender P Ghansela*

Manager—Production: *Reji Kumar*

Information contained in this work has been obtained by McGraw Hill Education (India), from sources believed to be reliable. However, neither McGraw Hill Education (India) nor its authors guarantee the accuracy or completeness of any information published herein, and neither McGraw Hill Education (India) nor its authors shall be responsible for any errors, omissions, or damages arising out of use of this information. This work is published with the understanding that McGraw Hill Education (India) and its authors are supplying information but are not attempting to render engineering or other professional services. If such services are required, the assistance of an appropriate professional should be sought.

Typeset at Tej Composers, WZ 391, Madipur, New Delhi 110 063 and printed at
A.P.Offset Pvt.Ltd., 25/487, Zulfe Bengal, Dilshad Garden, New Delhi-110095

Cover Printer: A.P.Offset Pvt.Ltd

RCCQCRQVDYQRB

Visit us at: www.mheducation.co.in

Contents

Foreword
Preface

xvii
xix

1. General Principles

1

- 1.1 Branches of Mechanics and Idealization in Mechanics 1
- 1.2 Vector and Scalar Quantities 3
- 1.3 Laws of Mechanics 4
- 1.4 Units of Physical Quantities 7
- 1.5 Dimensions of Physical Quantities 12
- 1.6 Solving Problems in Mechanics 15

Summary 16

Important Formulae 17

Short-Answer Questions 18

Key Terms 18

Review Questions 18

Objective Questions 19

Practice Problems 21

2. Force Systems and Resultants

22

- 2.1 Concept of Force 22
- 2.2 Representation of Force 23
- 2.3 Kinds of Vectors 24
- 2.4 Some Specific Vectors 24
- 2.5 System of Forces 25
- 2.6 Angle Between two Vectors 26
- 2.7 Addition of Vectors 27
- 2.8 Resolution of a Force 31
- 2.9 Using Rectangular Components to Add Vectors 34
- 2.10 Concept of Product 37

Additional Solved Examples 40

Summary 50

Important Formulae 51

<i>Short-Answer Questions</i>	51
<i>Key Terms</i>	52
<i>Review Questions</i>	52
<i>Objective Questions</i>	53
<i>Practice Problems</i>	55

3. Moments and Couples

59

3.1	Introduction	59
3.2	Moment of a Force	60
3.3	Graphical Representation and Sign Convention of Moment of a Force	61
3.4	Varignon's Theorem	62
3.5	Resultant of Parallel Forces	66
3.6	Couple	69
3.7	Translation of a Force to a Parallel Position	72
3.8	Reducing a Force-Couple System to a Single Force	73
3.9	Resultant of Planar Non-Concurrent Force System	75
	<i>Additional Solved Examples</i>	77
	<i>Summary</i>	84
	<i>Important Formulae</i>	85
	<i>Short-Answer Questions</i>	85
	<i>Key Terms</i>	86
	<i>Review Questions</i>	86
	<i>Objective Questions</i>	87
	<i>Practice Problems</i>	89

4. Equilibrium of Bodies

94

4.1	Necessary and Sufficient Conditions of Equilibrium for a Coplanar Force System	94
4.2	Conditions of Equilibrium for Different Types of Coplanar Force Systems	95
4.3	Types of Forces Acting on a Body	96
4.4	Free-Body Diagram	96
4.5	Principle of Equilibrium	97
4.6	Lami's Theorem	98
	<i>Additional Solved Examples</i>	103
	<i>Summary</i>	112
	<i>Important Formulae</i>	113
	<i>Short-Answer Questions</i>	114
	<i>Key Terms</i>	114
	<i>Review Questions</i>	114
	<i>Objective Questions</i>	115
	<i>Practice Problems</i>	116

5. Beams and Frames**121**

- 5.1 Introduction 121
- 5.2 Classification of Loading 122
- 5.3 Types of Support 123
- 5.4 Classification of Beams 123
- 5.5 Support Reactions 125
- 5.6 Internal Reactions in Beams 130
- 5.7 Shear Force and Bending Moment Diagrams 131
- 5.8 Differential Equations of Equilibrium—Relation between w , S and M 137
- 5.9 Properties of Shear Force and Bending Moment 138
- 5.10 Frames 142
 - Additional Solved Examples* 144
 - Summary* 161
 - Important Formulae* 162
 - Short-Answer Questions* 162
 - Key Terms* 163
 - Review Questions* 163
 - Objective Questions* 164
 - Practice Problems* 166

6. Trusses and Cables**170**

- 6.1 Introduction 170
- 6.2 Trusses 170
- 6.3 Fundamentals of Trusses 173
- 6.4 Analysis of Trusses 175
- 6.5 Cables 182
 - Additional Solved Examples* 194
 - Summary* 208
 - Important Formulae* 208
 - Short-Answer Questions* 209
 - Key Terms* 210
 - Review Questions* 210
 - Objective Questions* 210
 - Practice Problems* 212

7. Friction**217**

- 7.1 Introduction 217
- 7.2 Laws of Friction 221
- 7.3 Conditions of Friction Development 221
- 7.4 Ladder Friction and Wedge Friction 224
- 7.5 Rolling Friction 227
- 7.6 Advantages and Disadvantages of Friction 228

<i>Additional Solved Examples</i>	229
<i>Summary</i>	241
<i>Important Formulae</i>	242
<i>Short-Answer Questions</i>	242
<i>Key Terms</i>	242
<i>Review Questions</i>	243
<i>Objective Questions</i>	243
<i>Practice Problems</i>	244

8. Simple Lifting Machines

8.1	Introduction	248
8.2	Terminology	249
8.3	Losses in Machines	250
8.4	Reversible and Self-Locking Machines	252
8.5	Law of Machines	253
8.6	Maximum MA and Maximum η	253
8.7	Levers	254
8.8	Machines Based on Inclined Plane	256
8.9	Pulley Systems	264
8.10	Wheel-and-Axle Lifting Machines	268
	<i>Additional Solved Examples</i>	273
	<i>Summary</i>	279
	<i>Important Formulae</i>	279
	<i>Short-Answer Questions</i>	281
	<i>Key Terms</i>	281
	<i>Review Questions</i>	282
	<i>Objective Questions</i>	282
	<i>Practice Problems</i>	285

9. Centre of Gravity and Centroid

9.1	Introduction	288
9.2	Location of Centre of Gravity, Centre of Mass and Centroid	288
9.3	Centroids of Lines, Surfaces and Bodies	291
9.4	Centroids of Composite Bodies	303
9.5	Theorems of Pappus	305
	<i>Additional Solved Examples</i>	307
	<i>Summary</i>	324
	<i>Important Formulae</i>	324
	<i>Short-Answer Questions</i>	325
	<i>Key Terms</i>	325
	<i>Review Questions</i>	325

248

288

Objective Questions 326

Practice Problems 327

10. Moment of Inertia

332

10.1 Introduction 332

10.2 Moments of Inertia of Planes and Solids 332

10.3 Polar Moment of Inertia of an Area 333

10.4 Product of Inertia 334

10.5 Radius of Gyration 334

10.6 Parallel-Axis Theorem 335

10.7 Principal Moments of Inertia of an Area 343

Additional Solved Examples 347

Summary 379

Important Formulae 380

Short-Answer Questions 381

Key Terms 382

Review Questions 382

Objective Questions 382

Practice Problems 384

11. Virtual Work

390

11.1 Introduction 390

11.2 Principle of Virtual Work 393

11.3 Potential Energy 398

11.4 Stability of Equilibrium 400

Additional Solved Examples 403

Summary 413

Important Formulae 414

Short-Answer Questions 414

Key Terms 415

Review Questions 415

Objective Questions 415

Practice Problems 416

12. Motion in a Straight Line

421

12.1 Introduction 421

12.2 Important Terms 422

12.3 Motion with Constant Acceleration 425

12.4 Graphical Representation of Motion 428

12.5 Motion Under Gravity 433

12.6 Motion Under Variable Acceleration 438

12.7 Absolute and Relative Velocities 439

<i>Additional Solved Examples</i>	442	
<i>Summary</i>	450	
<i>Important Formulae</i>	451	
<i>Short-Answer Questions</i>	452	
<i>Key Terms</i>	452	
<i>Review Questions</i>	452	
<i>Objective Questions</i>	453	
<i>Practice Problems</i>	455	
13. Curvilinear Motion and Projectile		458
13.1 Introduction	458	
13.2 General Plane Curvilinear Motion	459	
13.3 Circular Motion	463	
13.4 Equations of Circular Motion	463	
13.5 Projectile Motion	465	
13.6 Projection on an Inclined Plane	471	
<i>Additional Solved Examples</i>	476	
<i>Summary</i>	489	
<i>Important Formulae</i>	490	
<i>Short-Answer Questions</i>	491	
<i>Key Terms</i>	491	
<i>Review Questions</i>	491	
<i>Objective Questions</i>	492	
<i>Practice Problems</i>	494	
14. Kinematics of Rigid Bodies		499
14.1 General Motion of a Rigid Body	499	
14.2 General Plane Motion	502	
14.3 Relative-Motion Analysis	505	
14.4 Instantaneous Centre of Velocity	512	
14.5 Problems Involving Connected Rigid Bodies	515	
<i>Additional Solved Examples</i>	516	
<i>Summary</i>	529	
<i>Important Formulae</i>	529	
<i>Short-Answer Questions</i>	530	
<i>Key Terms</i>	530	
<i>Review Questions</i>	530	
<i>Objective Questions</i>	531	
<i>Practice Problems</i>	532	
15. Kinetics of Particles and Rigid Bodies		537
15.1 Introduction	537	
15.2 Newton's Laws of Motion	537	

- 15.3 D'Alembert's Principle and Dynamic Equilibrium 540
- 15.4 Rigid Body in Pure Translation 541
- 15.5 Rigid Body Under Fixed-Axis Rotation 542
- 15.6 General Plane Motion of a Rigid Body 543
- 15.7 Motion of Vehicles on Level and Banked Roads 544
 - Additional Solved Examples* 548
 - Summary* 576
 - Important Formulae* 577
 - Short-Answer Questions* 578
 - Key Terms* 578
 - Review Questions* 579
 - Objective Questions* 579
 - Practice Problems* 580

16. Work, Energy and Power

585

- 16.1 Introduction 585
- 16.2 Energy 591
- 16.3 Work-Energy Principle 593
- 16.4 Power and Efficiency 597
- 16.5 Conservative Forces 599
- 16.6 Conservation of Energy 599
 - Additional Solved Examples* 602
 - Summary* 609
 - Important Formulae* 610
 - Short-Answer Questions* 610
 - Key Terms* 611
 - Review Questions* 611
 - Objective Questions* 611
 - Practice Problems* 612

17. Impulse and Momentum

615

- 17.1 Introduction 615
- 17.2 Impulse and Momentum 615
- 17.3 Principle of Impulse-Momentum 617
- 17.4 Conservation of Linear Momentum 619
- 17.5 Angular Momentum 620
- 17.6 Collision of Bodies 622
- 17.7 Mechanism of Impact 624
- 17.8 Loss of Kinetic Energy During Impact 629
- 17.9 Oblique Central Impact 631
- 17.10 Solving Problems of Kinetics 632
 - Additional Solved Examples* 634

<i>Summary</i>	641
<i>Important Formulae</i>	642
<i>Short-Answer Questions</i>	642
<i>Key Terms</i>	643
<i>Review Questions</i>	643
<i>Objective Questions</i>	643
<i>Practice Problems</i>	646

18. Belt and Rope Drives

18.1	Introduction	651
18.2	Belt Drives	653
18.3	Power Transmission by a Belt Drive	654
18.4	Velocity Ratio	655
18.5	Length of Belt	658
18.6	Belt Friction and Ratio of Tensions	661
18.7	Tension in the Belt	664
18.8	Maximum Power Transmitted	665
	<i>Additional Solved Examples</i>	666
	<i>Summary</i>	679
	<i>Important Formulae</i>	680
	<i>Short-Answer Questions</i>	681
	<i>Key Terms</i>	681
	<i>Review Questions</i>	681
	<i>Objective Questions</i>	682
	<i>Practice Problems</i>	684

651

19. Vibrations

19.1	Introduction	687
19.2	Graphical Representation of Free Vibration	688
19.3	Undamped Free Vibration	691
19.4	Damped Free Vibration	692
19.5	Undamped Forced Vibration	695
19.6	Damped Forced Vibration	696
19.7	Pendulum Motion	697
19.8	Combinations of Springs	700
	<i>Additional Solved Examples</i>	702
	<i>Summary</i>	712
	<i>Important Formulae</i>	713
	<i>Short-Answer Questions</i>	713
	<i>Key Terms</i>	714
	<i>Review Questions</i>	714

687

Objective Questions 714

Practice Problems 715

20. Simple Stresses and Strains

719

- 20.1 Introduction 719
- 20.2 Stress 719
- 20.3 Strain 721
- 20.4 The Three Moduli 722
- 20.5 Stress-Strain Curve for Mild Steel 723
- 20.6 Hooke's Law 726
- 20.7 Working Stress and Factor of Safety 728
- 20.8 Temperature Stresses 729
- 20.9 Strain Energy 730
- 20.10 Poisson's Ratio 731
- 20.11 Generalized Hooke's Law 732
 - Additional Solved Examples* 735
 - Summary* 741
 - Important Formulae* 742
 - Short-Answer Questions* 742
 - Key Terms* 743
 - Review Questions* 743
 - Objective Questions* 743
 - Practice Problems* 745

21. Bending and Torsion

748

- 21.1 Introduction 748
- 21.2 Pure Bending 749
- 21.3 Theory of Pure Bending 749
- 21.4 Section Modulus 753
- 21.5 Pure Torsion 754
- 21.6 Torsion Formula 755
- 21.7 Power Transmitted by the Shaft 757
 - Additional Solved Examples* 759
 - Summary* 768
 - Important Formulae* 769
 - Short-Answer Questions* 769
 - Key Terms* 770
 - Review Questions* 770
 - Objective Questions* 771
 - Practice Problems* 773

ENGINEERING MECHANICS

Statics and Dynamics

Written with pedagogy following internationally accepted outcome-based learning, this textbook deals with the basics of Statics, Dynamics, and introductory aspects of Solid Mechanics, meeting the requirements of an undergraduate course in Engineering Mechanics. The concepts are well-explained using diagrams drawn with engineering accuracy. Illustrative examples and problems for practice provided in the book will enhance the learning of the students.

Salient Features:

- ❖ **Learning Objectives** - Each chapter begins with a list of key Learning Objectives directly tied to the chapter content including the pedagogy. These help focus on planning for instructors and studying for students.
- ❖ **Levels of Difficulty** - All examples and problems - theoretical and numerical - are linked with Learning Objectives and graded as per Levels of Difficulty (LoD).
- ❖ **Myth & Fact** - During the study of a subject, students often develop and strongly believe in some misconceptions. Such myths and their corresponding facts are highlighted to clear students' doubts.
- ❖ **Short-Answer Questions** - These questions (along with their answers) provided at the end of each chapter not only prepare the students for viva-voce, but also relate the concepts to real-life engineering problems.

To access Solutions Manual and PowerPoint Lecture Slides, please visit
<http://highered.mheducation.com/sites/9339219171>

Write to us at
info.india@mheducation.com

**Mc
Graw
Hill**
Education

www.mheducation.co.in

ISBN-13: 978-93-392-1917-8

ISBN-10: 93-392-1917-1



9 789339 219178