BASIC ENGINEERING MECHANICS

Other titles of interest to engineers

An Introduction to Engineering Fluid Mechanics

J. A. Fox

Principles of Engineering Thermodynamics

E. M. Goodger

Analysis and Presentation of Experimental Results

R. H. Leaver and T. R. Thomas

A Background to Engineering Design

Peter Polak

Mechanics of Machines

G. H. Ryder and M. D. Bennett

Essential Solid Mechanics – Theory, worked examples and problems

B. W. Young

BASIC ENGINEERING MECHANICS

J. H. HUGHES

K. F. MARTIN

*Department of Mechanical Engineering
and Engineering Production, UWIST*

M

© J. H. Hughes and K. F. Martin 1977

All rights reserved. No part of this publication may
be reproduced or transmitted, in any form or by any means
without permission.

First published 1977 by
THE MACMILLAN PRESS LTD
London and Basingstoke
Associated companies in New York Dublin
Melbourne Johannesburg and Madras

ISBN 978-1-349-02451-3

ISBN 978-1-349-02449-0 (eBook)

DOI 10.1007/978-1-349-02449-0

This book is sold subject to the standard conditions of the Net Book Agreement.

The paperback edition of this book is sold subject to the condition that it shall
not, by way of trade or otherwise, be lent, resold, hired out, or otherwise
circulated without the publisher's prior consent in any form of binding or
cover other than that in which it is published and without a similar condition
including this condition being imposed on the subsequent purchaser.

Contents

<i>Preface</i>	ix
1 Introduction	1
1.1 Concept: Postulate: Law	1
1.2 Dimensions and Units	2
1.3 Statics and Dynamics	3
1.4 Mathematical Considerations	4
2 Fundamentals	5
2.1 Particle: Rigid Body: System	5
2.2 Scalars and Vectors	6
2.3 Addition of Vectors	6
2.4 Components and Unit Vectors	8
2.5 Units	10
2.6 Solution of Problems	11
3 Statics of a Particle	13
3.1 Resultant: Components	13
3.2 Equilibrium: Newton's First Law	15
3.3 Conditions for Equilibrium	15
3.4 Applications	16
3.5 Summary	18
4 Statics of Rigid Bodies	21
4.1 Newton's Third Law	21
4.2 Principle of Transmissibility	22
4.3 Resultant: Parallel Forces: Couples	22
4.4 Centre of Parallel Forces	24
4.5 Moment of a Force	25
4.6 Moment of a Couple	26
4.7 Force – Couple Sets	27
4.8 Coplanar Forces: Resultant	28
4.9 Conditions for Equilibrium	30
4.10 Solution of Problems	31
4.11 Composite and Connected Bodies	33
4.12 Simple Trusses	37
4.13 Simple Frames	40
4.14 Summary	47

5	Friction	57
5.1	Characteristics of Dry Friction	57
5.2	Some Practical Applications	67
5.3	Summary	83
6	Virtual Work	91
6.1	Work	91
6.2	Principle of Virtual Work	93
6.3	Applications: Connected Bodies	94
6.4	Connected Bodies: Friction and Elastic Members	96
6.5	Systems with Two Degrees of Freedom	98
6.6	Summary	100
7	Centres of Gravity and of Mass: Centroids	104
7.1	Centre of Gravity	104
7.2	Centres of Gravity: Standard Cases	107
7.3	Centre of Mass	112
7.4	Centroids of Lines, Surfaces and Volumes	113
7.5	Theorems of Pappus and Guldinus	114
7.6	Summary	118
8	Kinematics of a Particle	123
8.1	Rectilinear Motion of a Particle	123
8.2	Curvilinear Motion of a Particle	134
8.3	Angular Motion of a Line	143
8.4	Simple Harmonic Motion	145
8.5	Relative Motion of Particles	148
8.6	Summary	159
9	Kinetics of Particles and Particle Systems I – Equations of Motion	164
9.1	Equations of Motion for a Particle	164
9.2	Equations of Motion for a Particle System	170
9.3	Solution of Problems	174
9.4	Connected Particles	175
9.5	Summary	179
10	Kinetics of Particles and Particle Systems II – Integrated Forms	185
10.1	Linear Impulse and Linear Momentum	186
10.2	Conservation of Linear Momentum	190
10.3	Impulsive Forces	192
10.4	Impact	192
10.5	Work and Kinetic Energy	203

10.6	Evaluation of Work in Standard Cases	209
10.7	Potential Energy and Conservative Forces	213
10.8	Extraneous Forces	216
10.9	Summary	220
11	Kinematics of Rigid Bodies	226
11.1	Types of Rigid Body Motion	226
11.2	Instantaneous Centre of Rotation	232
11.3	Engineering Applications	236
11.4	Velocity and Acceleration Diagrams	242
11.5	Analytical Methods	248
11.6	Summary	252
12	Moments of Inertia	262
12.1	Moment of Inertia and Radius of Gyration	262
12.2	Theorems	262
12.3	Standard Forms	268
12.4	General Method for Calculating I for Complex Bodies	274
12.5	Summary	278
13	Kinetics of a Rigid Body	283
13.1	Equations of Motion	283
13.2	Impulse and Momentum	295
13.3	Work and Energy	312
13.4	Problems Involving Friction	325
13.5	Composite Problems	332
13.6	Summary	338
	<i>Appendix</i>	351
	<i>Answers to Problems</i>	355
	<i>Index</i>	361

Preface

The aim of this text is to present a systematic development of elementary applied mechanics assuming a mathematical background of elementary algebra, geometry and calculus. A knowledge of the principles of Newtonian mechanics is fundamental to the solution of many engineering problems and is a prerequisite for the study of more advanced texts; it is hoped that the treatment here will provide sufficient material on which this knowledge can be based.

Our experience leads us to believe that a return to basic principles is often desirable, and is particularly necessary for new engineering undergraduates who, in spite of having been exposed to previous instruction, frequently display a lack of familiarity with the meaning and significance of certain basic ideas. It is to this category that the book is mainly addressed, namely first-year students studying for an engineering degree or equivalent, who have some acquaintance with the subject matter but who require a more thorough grounding. The book is designed to cover the applied-mechanics content of the first year of an engineering degree course but will, in many cases, also provide a significant contribution to the second-year syllabus in mechanics of machines.

The traditional subdivision into statics and dynamics has been retained in order that familiarity may initially be gained with forces and their manipulation. We do not wish to appear pedantic in this matter since we recognise that there may be an equally good case for placing the initial emphasis on the concept of mass. Unfortunately it is difficult at this elementary level to treat one without the other, and a choice has to be made.

Having expressed Newton's laws in terms of particle behaviour the development of both statics and dynamics proceeds by way of particle systems to rigid bodies and systems of rigid bodies, incorporating in some cases a limited number of elastic elements.

In order to keep the discussion within reasonable bounds certain topics have been purposely omitted in the knowledge that detailed treatments are available elsewhere. For example, a more comprehensive study of the methods of structural analysis is better left to those books devoted to this topic. More important is the limitation of the discussion in the main to topics in two dimensions. This is in accord with the elementary nature of the book, but the decision was also based on the belief that the extension to three dimensions is facilitated by a thorough grounding in the basic principles that we hope this book will provide.

The inertia-force method of solution is given prominence for dealing with problems involving acceleration. Objection is raised by many, whose views we respect, on the grounds that the method is of historical interest only, and that it is used to assist in solving problems whose solution using dynamical principles requires no such assistance. We do not think these objections are completely valid; we maintain that the method has its merits and does nothing to relieve the student of the necessity of fully understanding the dynamics of the problem.

Our justification for writing yet another book on applied mechanics is that we felt there was a gap between those of very elementary nature and the more comprehensive texts that give rather more coverage than we considered necessary at this level, and that this gap could be filled by a book based on elementary mathematical knowledge but in which the argument was carefully developed. Also, by imposing the limitations already mentioned, we hope that the book will be within the financial reach of the student we wish to address. With these considerations in mind we claim no originality for the subject matter, the principles of which have long been recognised. However, we hope that the presentation, including the worked examples, chapter summaries and hints to problems, will be found of direct assistance to the student.

The book is separated into thirteen chapters with sections and subsections identified by a decimal notation; for example, 2.3.4 refers to subsection 2.3.4 in chapter 2. Equations relating to the text also carry a decimal notation and are numbered consecutively through each chapter; for example, the fifth equation in chapter 2 is numbered 2.5. Figure numbers again use the decimal notation and are numbered consecutively through each chapter including those relating to worked examples and problems. Answers to problems are assembled at the back of the book in the hope that students will exercise some restraint before consulting these.

We wish to acknowledge the encouragement of several colleagues in making comments on certain chapters, also the unstinting help of our typists, in particular Mrs Wilma Scott.