MECHANICS OF STRUCTURES
Vol. I

[A TEXT-BOOK FOR ENGINEERING STUDENTS]

by

S. B. JUNNARKAR

M.B.E., B.A., B.Sc. (Hons.), (Engg.), London

Formerly,

Principal, Birla Vishvakarma Mahavidyalaya
Vallabh Vidyanagar
and N.E.D. Engineering College, Karachi
Sometime, Dean of the Faculty of Technology including
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[WITH 450 DIAGRAMS, NUMEROUS ILLUSTRATIVE PROBLEMS AND EXERCISES]

[NINETEENTH EDITION]

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MECHANICS OF STRUCTURES

VOL. I

[IN MKS UNITS AND SI UNITS]

BOOKS

by

S. B. JUNNARKAR

ELEMENTS OF APPLIED MECHANICS

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KEY TO APPLIED MECHANICS

⊙

MECHANICS OF STRUCTURES
Vol. I

⊙

KEY TO MECHANICS OF STRUCTURES
Vol. I

⊙

MECHANICS OF STRUCTURES
Vol. II

[Including Theory and Design of Structures]

⊙

KEY TO MECHANICS OF STRUCTURES
Vol. II

⊙

MECHANICS OF STRUCTURES
Vol. III

[Including Advanced Theory of Structures]

⊙

ENGINEERING MECHANICS

[For Diploma Students]

⊙

SI UNITS

To

My Students

PREFACE

The approach of an average student to the study of this fascinating subject is, somehow, one of unreasoning dread. An attempt has been made in this book to present the principles as simply as possible and to illustrate them with a variety of worked-out examples. A student who goes through the text and takes the trouble of solving the exercises at the end of each chapter will, it is hoped, be better equipped to study with profit the many excellent standard works on the subject.

I am particularly grateful to Mr. R. S. Dighe, B.E.,A.M.I.E., of the Faculty of Technology, for undertaking the arduous and monotonous task of checking up all numerical work, which he has done cheerfully. My thanks are due to Mr. T. N. Joshi, B.Sc. (Eng.), of the Faculty of Technology for making all the sketches required for the blocks which were made by Mr. N. B. Joglekar of the Faculty of Fine Arts, to whom I am grateful.

I am specially indebted to Mr. R. C. Patel of the Charotar Book Stall, Anand, and to Mr. V. B. Priyani, B.E.,A.M.I.E., of Birla Vishvakarma Mahavidyalaya, who spared no efforts in the tedious task of correcting the proofs, and to Mr. K. A. Damle, B.Sc., Librarian of the Faculty of Technology, who checked the final proofs. My thanks are due to Mr. B. G. Marathe, also of the Faculty of Technology, who took considerable pains in preparing the typescript of the text.

I am indebted to the Syndics of the Universities of Cambridge, London and Bombay, for their kind permission to make use of a few problems set at their University Examinations.

I should like to express my sincere appreciation of the great care and trouble which have been taken by the Anand Press, Anand, in the printing and get-up of this book.

Inspite of all the pains taken by Mr. R. S. Dighe, it is possible that some errors have escaped our attention. I shall be grateful if they are brought to my notice.

Faculty of Technology
including Engineering
Baroda
May, 1952

S. B. JUNNARKAR

SIXTH EDITION

In this revised edition, the metric system of units entirely replaces the F.P.S. system used in the earlier texts. The subject matter has been revised wherever necessary to make it up-to-date. Some typical illustrative examples have also been added.

Poona S. B. J.
October, 1967

SEVENTH EDITION

In this enlarged edition, the text has been revised and brought up-to-date. Many of the old stereo-typed examples have been replaced by fresh ones based on the latest papers set at University and professional examinations.

Appendices on Mohr circle, Unsymmetrical beam-sections, Conjugate beam method, Welded joints, etc. have been added.

The reader will notice that the symbols used for Bending Moments, Torques, etc. are kg cm, kg m or t m, instead of cm kg, m kg, m t used hitherto — for reasons stated in the Note on Units at the end of the book.

In the Appendix on SI Units, besides the standard stress-unit N/m^2, its approved multiple MN/m^2, which, in effect, is N/mm^2, has been introduced. A good number of examples in SI units have also been included in the main text at the end of some chapters.

It is hoped that with these additions, the book in its enlarged and revised form, will be found more useful.

Poona S. B. J.
January, 1972

EIGHTH EDITION

In this edition, a chapter on the method of "Tension Coefficients" has been added, as it forms a complement to the study of "Stresses in Frames."

More examples in SI units have been added at the ends of chapters. The appendix on SI units has been revised.

468 C/2 Ganeshkhind Road,
Poona–16 S. B. J.
October, 1974

SEVENTEENTH EDITION

This edition has been thoroughly revised and enlarged. Appendices A—E added in the earlier editions are replaced by adding five new chapter on Unsymmetrical Bending, Conjugate Beam Method, Welded Joints, Shear Centre, Bending Stresses in Curved Bars. This edition covers a sufficiently wide range of topics which are included in the syllabi of the degree and diploma courses. It also includes several illustrative examples, in both the MKS and SI units, based on the types set at the various University examinations in India and abroad. The change over from the MKS to the SI, it will be seen, is not at all difficult.

This edition will also be useful to those preparing for the A.M.I.E. and competitive examinations. The basic approach of the late Principal S. B. Junnarkar, which is noted for its unusual clarity, has been retained.

Thanks are due to Shri S. S. Deo, Shri J. N. Aurangabadkar and Shri C. B. Kugaokar of the Government Polytechnic, Solapur, for their valuable assistance in preparing the manuscript.

We also sincerely thank Prof. S. C. Rangwala, Ahmedabad, and Shri Ramanbhai C. Patel, Anand, for undertaking the dreary task of checking the proofs which they have done with great keenness and enthusiasm. We are equally indebted to Rev. Br. S. Abril and his staff of the Anand Press for the excellent work done by them in bringing out this volume.

Poona
January 26, 1981

H. V. ADAVI

NINETEENTH EDITION

This edition is reprinted with more attractive and clear printing. A few figures have been replaced by new drawings.

The publishers thank the students and teachers of the subject for their magnificent response to the book.

Suggestions will be gratefully accepted.

Anand
April 7, 1987

—PUBLISHERS

CONTENTS

Chapter 1

SI UNITS

1-1. Introductory: To students of science, who are used to *absolute* units of measurements, there is nothing novel about the SI units (Systéme Internationale d'Unités) which, essentially, are the *absolute* units of the current m.k.s. system.

Most systems adopt three basic units of Length, Mass and Time, besides using some other arbitrary units for purposes of measurement. The SI rationalizes the available units and streamlines them into a coherent logical system. It reduces the number of *basic* units — arbitrarily selected — to a minimum and derives all the other units required, from these basic units.

The symbols and notation of SI units and their derivatives are standardized to avoid any possibility of confusion.

1-2. Basic units: SI uses *six* arbitrarily chosen *basic* units, listed below:

BASIC SI UNITS

No.	Physical quantity	Name of SI units	Symbol
1.	Length	metre	m
2.	Mass	kilogramme	kg
3.	Time	second	s
4.	Electrical current	ampere	A
5.	Temperature	kelvin	K
6.	Luminous intensity	candela	cd

The temperature t °C implies that $T = (t + 273{\cdot}15)$ °K.

1-3. Derived units: Force: Work: Power: Practically all other units used in Science and Technology are derived from these basic units. We have said that the SI systematizes them into a *coherent* logical scheme. A system is coherent, if the product or quotient of any two unit quantities in the system is the unit of the resulting derived quantity. When the unit of length is multiplied by the unit of length, the result is the unit of area. When the unit of length is divided by the unit of time, the result is the unit of velocity. When the unit of mass is multiplied by the unit of acceleration, the result is the unit of force.

Force:

The unit of force called the *"Newton" is that force which, when applied to a body having a mass of one kilogramme gives it an acceleration of one metre per second squared.* It will be noticed that this is also the *absolute* unit of force in the m.k.s. system. Newton's Second Law of Motion says that the rate of change of momentum in a moving body is proportional to the impressed force and takes place in the direction of the force. Expressed as an equation, $P = \lambda . mf$, the value of the constant λ, depending on the unit of force selected. In the SI, the *unit* of force is that, which in a *unit* mass produces *unit* acceleration, so that the constant λ is, ipso facto, *unity*. In SI, the main departure from the traditional metric system is the adoption of "Newton" as the standard unit of force. Its symbolic notation is "N".

One kilo-Newton (kN) = 10^3 Newtons.
One mega-Newton (MN) = 10^6 Newtons.
One giga-Newton (GN) = 10^9 Newtons.

Incidentally, *SI has discarded the gravitational unit*, which has been universal hitherto.

Work: Energy:

The unit of work or energy is a *Newton-metre* (N-m) called the *joule* (J) and *is the work done when the point of application of a force of one Newton is displaced through a distance of one metre in the direction of the force.*

One kilojoule (kJ) = 10^3 joules.

Power:

Power is defined as *the rate of doing work*. The unit of power is called the watt (W) and is equal to *one joule* or *Newton-metre per second* (J/s or N-m/s).

One kilo-watt (kW) = 10^3 watts
One mega-watt (MW) = 10^6 watts.

A horse power (h.p.) as a measure of power has no place in the SI, as the watt (W), the kilo-watt (kW) and the mega-watt (MW) meet all the requirements for measurement of power.

1-4. Multiples and Sub-multiples of SI units: While the essential SI units with their derivatives are well-defined, it is often necessary to use the multiples and sub-multiples of these. Thus, while a metre (m) is the standard unit of length, we use a kilometre (km) to measure long distances. One kilometre = 10^3 metres. Similarly, while a watt (W) is the standard unit of power, it is too small a unit and so we use a kilo watt (kW) or a mega-watt (MW) for measurement of power. These multiples and sub-multiples are in decimals.

Decimal multiples and sub-multiples of SI units are formed by means of prefixes as detailed below:

Factor by which the unit is multiplied	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

In SI, the use of prefixes representing 10 raised to powers which are multiples of 3 is preferred. Therefore, the use of prefixes — hecto, deca, deci and centi is not recommended.

In forming decimal multiples and sub-multiples of a derived SI unit, as far as possible, only one prefix should be used; preferably it should be attached to the numerator. For example, for pressure or stress — which is force per unit area — the standard unit is Newton per metre squared — N/m^2. [1 Pascal (Pa) = 1 N/m^2.] If a multiple or sub-multiple has to be used,