时代教育 • 国外高校优秀教材精选

材料力学

（英文版·原书第5版）

Mechanics of Materials

机械工业出版社
CHINA MACHINE PRESS

（美）J.M.盖尔（James M.Gere）著

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CONVERSIONS BETWEEN U.S. CUSTOMARY UNITS AND SI UNITS (Continued)

U.S. Customary unit		Times conversion factor		Equals SI unit	
		Accurate	Practical		
Moment of inertia (area)					
inch to fourth power	in.^{4}	416,231	416,000	millimeter to fourth power	mm^4
inch to fourth power	in.^{4}	0.416231×10^{-6}	0.416×10^{-6}	meter to fourth power	m^4
Moment of inertia (mass)					
slug foot squared	slug-ft^2	1.35582	1.36	kilogram meter squared	kg·m^2
Power					
foot-pound per second	ft-lb/s	1.35582	1.36	watt (J/s or N·m/s)	W
foot-pound per minute	ft-lb/min	0.0225970	0.0226	watt	W
horsepower (550 ft-lb/s)	hp	745.701	746	watt	W
Pressure; stress					
pound per square foot	psf	47.8803	47.9	pascal (N/m^2)	Pa
pound per square inch	psi	6894.76	6890	pascal	Pa
kip per square foot	ksf	47.8803	47.9	kilopascal	kPa
kip per square inch	ksi	6.89476	6.89	megapascal	MPa
Section modulus					
inch to third power	in.^{3}	16,387.1	16,400	millimeter to third power	mm^3
inch to third power	in.^{3}	16.3871×10^{-6}	16.4×10^{-6}	meter to third power	m^3
Velocity (linear)					
foot per second	ft/s	0.3048*	0.305	meter per second	m/s
inch per second	in./s	0.0254*	0.0254	meter per second	m/s
mile per hour	mph	0.44704*	0.447	meter per second	m/s
mile per hour	mph	1.609344*	1.61	kilometer per hour	km/h
Volume					
cubic foot	ft^3	0.0283168	0.0283	cubic meter	m^3
cubic inch	in.^{3}	16.3871×10^{-6}	16.4×10^{-6}	cubic meter	m^3
cubic inch	in.^{3}	16.3871	16.4	cubic centimeter (cc)	cm^3
gallon (231 in.^{3})	gal.	3.78541	3.79	liter	L
gallon (231 in.^{3})	gal.	0.00378541	0.00379	cubic meter	m^3

*An asterisk denotes an *exact* conversion factor

***Note:* To convert from SI units to USCS units, *divide* by the conversion factor**

Temperature Conversion Formulas

$$T(°C) = \frac{5}{9}[T(°F) - 32] = T(K) - 273.15$$

$$T(K) = \frac{5}{9}[T(°F) - 32] + 273.15 = T(°C) + 273.15$$

$$T(°F) = \frac{9}{5}T(°C) + 32 = \frac{9}{5}T(K) - 459.67$$

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出版说明

随着我国加入WTO，国际间的竞争越来越激烈，而国际间的竞争实际上也就是人才的竞争、教育的竞争。为了加快培养具有国际竞争力的高水平技术人才，加快我国教育改革的步伐，国家教育部近来出台了一系列倡导高校开展双语教学、引进原版教材的政策。以此为契机，机械工业出版社拟于近期推出一系列国外影印版教材，其内容涉及高等学校公共基础课，以及机、电、信息领域的专业基础课和专业课。

引进国外优秀原版教材，在有条件的学校推动开展英语授课或双语教学，自然也引进了先进的教学思想和教学方法，这对提高我国自编教材的水平，加强学生的英语实际应用能力，使我国的高等教育尽快与国际接轨，必将起到积极的推动作用。

为了做好教材的引进工作，机械工业出版社特别成立了由著名专家组成的国外高校优秀教材审定委员会。这些专家对实施双语教学做了深入细致的调查研究，对引进原版教材提出许多建设性意见，并慎重地对每一本将要引进的原版教材一审再审，精选再精选，确认教材本身的质量水平，以及权威性和先进性，以期所引进的原版教材能适应我国学生的外语水平和学习特点。在引进工作中，审定委员会还结合我国高校教学课程体系的设置和要求，对原版教材的教学思想和方法的先进性、科学性严格把关，同时尽量考虑原版教材的系统性和经济性。

这套教材出版后，我们将根据各高校的双语教学计划，举办原版教材的教师培训，及时地将其推荐给各高校选用。希望高校师生在使用教材后及时反馈意见和建议，使我们更好地为教学改革服务。

机械工业出版社

2002年3月

序

如果推出一本首选的英文版《材料力学》，恐怕不少人会选作者为盖尔（James M. Gere）的“Mechanics of Materials”（第5版，2001年）。

“首选”它的原因，并不是因较之其以前的4个版本（1972年、1984年、1990年、1997年）更加完善和可读，也不是因插图更加清晰和精美：积累产生的进化——任何多次再版的书皆可以做得到。首选的根本原因在于它是材料力学教材中“铁摩辛柯（Stephen P. Timoshenko）体系”的代表作。

本书的第1版是盖尔在铁摩辛柯的倡导和建议下编写的，虽然铁摩辛柯没有直接参加写作，但是他提供了很多内容，可以说，第1版基于或借鉴了铁摩辛柯早期的两本题为“Strength of Materials”的书。因此，第1版的作者署名是铁摩辛柯和盖尔。

众所周知，集力学家与教育家于一身的铁摩辛柯是应用力学的开拓者之一，他曾经贡献了许多新思想和新概念，他写的13本兼有基础和前沿内容的力学教科书，译成了35种文字，具有广泛的国际影响。

本书作为“铁摩辛柯体系”，属于材料力学的“归纳法体系”，它与后来出现的材料力学的“演绎法体系”，在讲授内容的组织和教科书结构构造上，形成相反的风格：前者是从个别到一般的逻辑体系，后者是从一般到个别的逻辑体系。

材料力学从无到有的发展历程，是一个归纳的过程，“铁摩辛柯体系”或“归纳法体系”以学科的“逻辑”反映了“历史”的演变，大概是因为符合“历史与逻辑一致”的原理，有利于初学者从个别到一般、由感性到理性地把握这门变形体力学的入门课，所以多数的材料力学课堂还在坚持这个体系。也许这一体系有助于培养学生们的创新能力，熏陶他们的综合素质。

顺便提一下，尽管“演绎法体系”使材料力学像一门“小弹性力学”，对于变形体力学入门课程的初学者会有一些困难，然而，“演绎法体系”身体力行者对于内容重组、学科整合、结构再建的开拓和革新的精神是令人钦佩的。

“归纳法体系”与“演绎法体系”决不应是相互排挤的，而应当是对偶和互补的关系，可以互相竞争、互相借鉴、互为推动、携手发展。事实上，已经看到了二者相互渗透和融合的教材。

材料力学是机械、土木、航空、航天、船舶、车辆、矿山等专业的必修课，也是材料科学、工业工程、建筑学乃至农业工程等专业学生值得学习的课程。

本书有如下几个特点：

1. 强调基本，突出重点。本书的主题围绕拉、压、扭、弯的分析与设计，涉及到应力、应变、变形、位移、弹性、非弹性、应变能、承载能力这些基本概念。本书同不少归纳法体系教科书有一些不同的处理，没有把动载荷、疲劳、塑性等内容单独列章，而是像应力集中、温度效应那样放在各章之中作为非基本内容予以介绍，也许还是旨在突出基本内容。

2. 能够坚持千锤百炼的传统内容。本书中看不到追赶“内容更新”潮流的痕迹，关于这一点，也许会有“仁者见仁、智者见智”的不同见解，但是，材料力学既然属于工程技术的基础课，就不宜把从它

派生出来的其他学科分支的内容，取出来挤自己的基本概念，充塞在课程体系之中。从根本上讲，本书没有用“流”去冲击“源”，实乃明智之举。

3. 分出层次，方便学习。不仅各章中用星号 * 注明特殊，提醒不是基本内容，而且精选的 1000 多道习题也用一个或多个星号 * 表示该问题的困难程度；单位制上按奇数和偶数分别采用英制和国际单位制，既适应美国工程界的实际，又有利于国际标准的贯彻，当然也有利于非美英国家的读者。

4. 能使读者看到知识发生的轨迹。本书的最后一章后面列出了学科发展的重要参考文献和有关历史注记，列举了构筑材料力学学科的力学家、工程师和数学家的简要介绍，并且列出了人名索引。这种重视对原创性资料揭示的做法，从力学史和方法论的角度看，是一件篇幅小、意义大的好事。

总之，本书是一本经过长期教学实践锤炼的经典教材，可读性很强，影印本恰逢教育部提倡双语教学之际出版，不仅有利于材料力学教师把它作为一本很好的参考书，同时也有利于广大学生把它作为一本实用的英文版材料力学教材。

隋允康
北京工业大学
2002 年 8 月

Preface

Mechanics of materials is a basic engineering subject that must be understood by anyone concerned with the strength and physical performance of structures, whether those structures are man-made or natural. The subject matter includes such fundamental concepts as stresses and strains, deformations and displacements, elasticity and inelasticity, strain energy, and load-carrying capacity. These are the concepts that underlie the design and analysis of a huge variety of mechanical and structural systems.

At the college level, mechanics of materials is usually taught during the sophomore and junior years. It is a required subject for most students majoring in mechanical, structural, civil, aeronautical, and aerospace engineering. Furthermore, many students from such diverse fields as materials science, industrial engineering, architecture, and agricultural engineering also find it worthwhile to study this subject.

About this Book

The main topics covered in this book are the analysis and design of structural members subjected to tension, compression, torsion, and bending, including the fundamental concepts mentioned in the first paragraph. Other topics of general interest are the transformations of stress and strain, combined loadings, stress concentrations, deflections of beams, and stability of columns.

Specialized topics include thermal effects, dynamic loading, nonprismatic members, beams of two materials, shear centers, pressure vessels, and statically indeterminate beams. For completeness and occasional reference, elementary topics such as shear forces, bending moments, centroids, and moments of inertia also are presented.

Much more material than can be taught in a single course is included in this text and, therefore, instructors have the opportunity to select the topics they wish to cover. As a guide, some of the more specialized topics are identified by asterisks.

This Fifth Edition of *Mechanics of Materials* has been thoroughly edited to make it even more readable than before. Problems have been revised and improved, and all of the figures have been carefully redrawn for increased clarity and accuracy. As instructors of mechanics know, the figures in a book of this kind have an essential role in making the subject matter understandable.

Considerable effort has been spent in checking and proofreading the text so as to eliminate errors, but if you happen to find one, no matter how minor, please notify me by e-mail (jgere@ce.Stanford.edu) or write to me in care of the publisher. (All correspondence will be answered.)

Examples

Numerous examples are presented in order to illustrate the theoretical concepts and show how those concepts may be used in practical situations. The examples vary in length from one to four pages, depending upon the complexity of the material to be illustrated. When the emphasis is on concepts, the examples are worked out in symbolic terms so as to better illustrate the ideas, and when the emphasis is on problem-solving, the examples are numerical in character.

Problems

In any mechanics course, solving problems is an important part of the learning process. This text offers more than 1,000 problems for homework assignments and classroom discussions. The problems are placed at the end of each chapter so that they are easy to find and don't break up the presentation of the subject matter. Also, an unusually difficult or lengthy problem is indicated by attaching one or more stars (depending upon the degree of difficulty) to the problem number, thus alerting students to the time necessary for solution. Answers to all problems are listed near the back of the book.

Units

Both the International System of Units (SI) and the U.S. Customary System (USCS) are used in the examples and problems. Discussions of both systems and a table of conversion factors are given in Appendix A. For problems involving numerical solutions, odd-numbered problems are in USCS units and even-numbered problems are in SI units. This convention makes it easy to know in advance which system of units is being used in any particular problem. (The only exceptions are problems involving the tabulated properties of structural-steel shapes, because the tables for these shapes are presented only in USCS units.)

References and Historical Notes

References and historical notes appear immediately after the last chapter in the book. They consist of original sources for the subject matter plus biographical notes about the pioneering scientists, engineers, and mathematicians who created the subject of mechanics of materials. A separate name index makes it easy to look up any of these historical figures.

S. P. Timoshenko (1878–1972)

Many readers of this book will recognize the name of Stephen P. Timoshenko—probably the most famous name in the field of mechanics. Timoshenko appeared as co-author on earlier editions of this book because the book began at his instigation. The first edition, published in 1972, was written by the present author at the suggestion of Professor Timoshenko. Although Timoshenko did not participate in the actual writing, he provided much of the book's contents because the first edition was based heavily upon his two earlier books titled *Strength of Materials*. The second edition, a major revision of the first, was published many years later (in 1984), and each subsequent edition (in 1990 and 1997) has incorporated many new changes and improvements.

Timoshenko is generally recognized as the most outstanding pioneer in applied mechanics. He contributed many new ideas and concepts and became famous for both his scholarship and his teaching. As a teacher and lecturer, he was well-known for his ability to bring the subject matter of his classes to life. He wrote 13 major textbooks on both elementary and advanced subjects in mechanics, and these books have gone through many editions and been translated into a dozen languages. Through these books he made a profound change in the teaching of mechanics not only in this country but wherever mechanics is taught. His methodology was to start from a scientific and mathematical base and then develop the subject in a logical and step-by-step manner. Consequently, he raised the level of instruction and broadened our understanding of applied mechanics. (You can find a brief biography of Timoshenko in the first reference at the back of the book.)

Acknowledgments

To acknowledge everyone who contributed to this book in some manner is clearly impossible, but I owe a major debt to my former Stanford teachers, including (besides Timoshenko) those other pioneers in mechanics, Wilhelm Flügge, James Norman Goodier, Miklós Hetényi, Nicholas J. Hoff, and Donovan H. Young. I am also indebted to my Stanford colleagues—especially Tom Kane, Anne Kiremidjian, Helmut Krawinkler, Kincho Law, Peter Pinsky, Haresh Shah, Sheri Sheppard, and the late Bill Weaver. They provided me with many hours of discussions about mechanics and educational philosophy. My thanks also to Wayne Hamilton of the University of Maine for his valuable insights concerning Mechanics of Materials and its presentation.

The following reviewers provided both general and specific comments for changes and improvements in the book: Fred K. Bogner, University of Dayton; George R. Buchanan, Tennessee Technological

University; Walter R. Carnes, Mississippi State University; Chih-Chen Chang, Hong Kong University of Science and Technology; Mustafa Isreb, University of Monash; Denis Montgomery, University of Wollongong; and Richard Sayles, University of Maine. My sincere thanks and appreciation to each of these very helpful reviewers.

I was assisted in manuscript preparation and proofreading by Duc Wong, who worked with great care and accuracy. Many others helped with proofreading and the preparation of solutions for the problems. They include Mark Audigier, Kymberly Eliot, Mary Godfrey-Dickson, Racquel Hagen, Jerome Lynch, Gabriela Medina, Ricardo Medina, and Nuthaporn Nuttyasakul.

The editing and production aspects of the book were a source of great pleasure and satisfaction to me, because everyone I dealt with on the staff of the Brooks/Cole Publishing Company was extremely talented and knowledgeable. Furthermore, their goal was the same as mine—to produce the best possible book without stinting at any step of the way. The people with whom I had personal contact are Bill Stenquist, Publisher, who set the tone for excellence and provided both leadership and inspiration, Suzanne Jeans, Editor, who launched the book; Jamie Sue Brooks, Editorial Production Supervisor, who made sure that every phase of the work was handled to perfection; Jennifer Mackres, Art Editor, who handled the artwork with great skill; Vernon Boes, Art Director, who created the attractive design of the covers; Ellen Brownstein, Editorial Production Manager, who skillfully handled all phases of the work during the early stages; Shelley Gesicki, Editorial Coordinator, who monitored progress and kept us organized; and Rose Kernan of RPK Editorial Services, who supervised with great skill every aspect of the physical production of the book. To each of these individuals I express my heartfelt thanks not only for a job well done but also for the friendly and considerate way in which it was done.

Many other people who I did not meet personally also participated in the development of this book—for instance, the talented artists at Rolin Graphics, who prepared the figures and tolerated my nitpicking over details; and the typesetters at Better Graphics, who meticulously laid out every page of text. To each of these individuals, I also extend my sincere thanks for a job well done.

Finally, I appreciate the patience and encouragement provided by my family, especially my wife, Janice, throughout this project.

To all of these wonderful people, I am pleased to express my gratitude.

James M. Gere

Symbols

A	area
A_f, A_w	area of flange; area of web
a, b, c	dimensions, distances
C	centroid, compressive force, constant of integration
c	distance from neutral axis to outer surface of a beam
D	diameter
d	diameter, dimension, distance
E	modulus of elasticity
E_r, E_t	reduced modulus of elasticity; tangent modulus of elasticity
e	eccentricity, dimension, distance, unit volume change (dilatation)
F	force
f	shear flow, shape factor for plastic bending, flexibility, frequency (Hz)
f_T	torsional flexibility of a bar
G	modulus of elasticity in shear
g	acceleration of gravity
H	height, distance, horizontal force or reaction, horsepower
h	height, dimension
I	moment of inertia (or second moment) of a plane area
I_x, I_y, I_z	moments of inertia with respect to x, y, and z axes
I_{x_1}, I_{y_1}	moments of inertia with respect to x_1 and y_1 axes (rotated axes)
I_{xy}	product of inertia with respect to xy axes
$I_{x_1y_1}$	product of inertia with respect to x_1y_1 axes (rotated axes)
I_P	polar moment of inertia
I_1, I_2	principal moments of inertia
J	torsion constant
K	stress-concentration factor, bulk modulus of elasticity, effective length factor for a column
k	spring constant, stiffness, symbol for $\sqrt{P/EI}$
k_T	torsional stiffness of a bar
L	length, distance

L_E	effective length of a column
ln, log	natural logarithm (base e); common logarithm (base 10)
M	bending moment, couple, mass
M_P, M_Y	plastic moment for a beam; yield moment for a beam
m	moment per unit length, mass per unit length
N	axial force
n	factor of safety, integer, revolutions per minute (rpm)
O	origin of coordinates
O'	center of curvature
P	force, concentrated load, power
P_{allow}	allowable load (or working load)
P_{cr}	critical load for a column
P_P	plastic load for a structure
P_r, P_t	reduced-modulus load and tangent-modulus load for a column
P_Y	yield load for a structure
p	pressure (force per unit area)
Q	force, concentrated load, first moment of a plane area
q	intensity of distributed load (force per unit distance)
R	reaction, radius
r	radius, radius of gyration ($r = \sqrt{I/A}$)
S	section modulus of the cross section of a beam, shear center
s	distance, distance along a curve
T	tensile force, twisting couple or torque, temperature
T_P, T_Y	plastic torque; yield torque
t	thickness, time, intensity of torque (torque per unit distance)
t_f, t_w	thickness of flange; thickness of web
U	strain energy
u	strain-energy density (strain energy per unit volume)
u_r, u_t	modulus of resistance; modulus of toughness
V	shear force, volume, vertical force or reaction
v	deflection of a beam, velocity
v', v'', etc.	dv/dx, d^2v/dx^2, etc.
W	force, weight, work
w	load per unit of area (force per unit area)
x, y, z	rectangular axes (origin at point O)
x_c, y_c, z_c	rectangular axes (origin at centroid C)
$\bar{x}$, $\bar{y}$, $\bar{z}$	coordinates of centroid
Z	plastic modulus of the cross section of a beam

α	angle, coefficient of thermal expansion, nondimensional ratio
β	angle, nondimensional ratio, spring constant, stiffness
β_R	rotational stiffness of a spring
γ	shear strain, weight density (weight per unit volume)
$\gamma_{xy}, \gamma_{yz}, \gamma_{zx}$	shear strains in xy, yz, and zx planes
$\gamma_{x_1y_1}$	shear strain with respect to x_1y_1 axes (rotated axes)
γ_θ	shear strain for inclined axes
δ	deflection of a beam, displacement, elongation of a bar or spring
ΔT	temperature differential
δ_P, δ_Y	plastic displacement; yield displacement
ϵ	normal strain
$\epsilon_x, \epsilon_y, \epsilon_z$	normal strains in x, y, and z directions
$\epsilon_{x_1}, \epsilon_{y_1}$	normal strains in x_1 and y_1 directions (rotated axes)
ϵ_θ	normal strain for inclined axes
$\epsilon_1, \epsilon_2, \epsilon_3$	principal normal strains
ϵ'	lateral strain in uniaxial stress
ϵ_T	thermal strain
ϵ_Y	yield strain
θ	angle, angle of rotation of beam axis, rate of twist of a bar in torsion (angle of twist per unit length)
θ_p	angle to a principal plane or to a principal axis
θ_s	angle to a plane of maximum shear stress
κ	curvature ($\kappa = 1/\rho$)
λ	distance, curvature shortening
ν	Poisson's ratio
ρ	radius, radius of curvature ($\rho = 1/\kappa$), radial distance in polar coordinates, mass density (mass per unit volume)
σ	normal stress
$\sigma_x, \sigma_y, \sigma_z$	normal stresses on planes perpendicular to x, y, and z axes
$\sigma_{x_1}, \sigma_{y_1}$	normal stresses on planes perpendicular to x_1y_1 axes (rotated axes)
σ_θ	normal stress on an inclined plane
$\sigma_1, \sigma_2, \sigma_3$	principal normal stresses
σ_{allow}	allowable stress (or working stress)
σ_{cr}	critical stress for a column ($\sigma_{cr} = P_{cr}/A$)
σ_{pl}	proportional-limit stress
σ_r	residual stress
σ_T	thermal stress
σ_U, σ_Y	ultimate stress; yield stress

τ	shear stress
$\tau_{xy}, \tau_{yz}, \tau_{zx}$	shear stresses on planes perpendicular to the x, y, and z axes and acting parallel to the y, z, and x axes
$\tau_{x_1y_1}$	shear stress on a plane perpendicular to the x_1 axis and acting parallel to the y_1 axis (rotated axes)
τ_θ	shear stress on an inclined plane
τ_{allow}	allowable stress (or working stress) in shear
τ_U, τ_Y	ultimate stress in shear; yield stress in shear
ϕ	angle, angle of twist of a bar in torsion
ψ	angle, angle of rotation
ω	angular velocity, angular frequency ($\omega = 2\pi f$)

★A star attached to a section number indicates a specialized or advanced topic. One or more stars attached to a problem number indicate the level of difficulty in the solution.

Greek Alphabet

Α	α	Alpha	Ν	ν	Nu
Β	β	Beta	Ξ	ξ	Xi
Γ	γ	Gamma	Ο	o	Omicron
Δ	δ	Delta	Π	π	Pi
Ε	ϵ	Epsilon	Ρ	ρ	Rho
Ζ	ζ	Zeta	Σ	σ	Sigma
Η	η	Eta	Τ	τ	Tau
Θ	θ	Theta	Υ	υ	Upsilon
Ι	ι	Iota	Φ	ϕ	Phi
Κ	κ	Kappa	Χ	χ	Chi
Λ	λ	Lambda	Ψ	ψ	Psi
Μ	μ	Mu	Ω	ω	Omega

PRINCIPAL UNITS USED IN MECHANICS

Quantity	International System (SI)			U.S. Customary System (USCS)		
	Unit	Symbol	Formula	Unit	Symbol	Formula
Acceleration (angular)	radian per second squared		rad/s^2	radian per second squared		rad/s^2
Acceleration (linear)	meter per second squared		m/s^2	foot per second squared		ft/s^2
Area	square meter		m^2	square foot		ft^2
Density (mass) (Specific mass)	kilogram per cubic meter		kg/m^3	slug per cubic foot		$slug/ft^3$
Density (weight) (Specific weight)	newton per cubic meter		N/m^3	pound per cubic foot	pcf	lb/ft^3
Energy; work	joule	J	N·m	foot-pound		ft-lb
Force	newton	N	$kg \cdot m/s^2$	pound	lb	(base unit)
Force per unit length (Intensity of force)	newton per meter		N/m	pound per foot		lb/ft
Frequency	hertz	Hz	s^{-1}	hertz	Hz	s^{-1}
Length	meter	m	(base unit)	foot	ft	(base unit)
Mass	kilogram	kg	(base unit)	slug		$lb\text{-}s^2/ft$
Moment of a force; torque	newton meter		N·m	pound-foot		lb-ft
Moment of inertia (area)	meter to fourth power		m^4	inch to fourth power		$in.^4$
Moment of inertia (mass)	kilogram meter squared		$kg \cdot m^2$	slug foot squared		$slug\text{-}ft^2$
Power	watt	W	J/s (N·m/s)	foot-pound per second		ft-lb/s
Pressure	pascal	Pa	N/m^2	pound per square foot	psf	lb/ft^2
Section modulus	meter to third power		m^3	inch to third power		$in.^3$
Stress	pascal	Pa	N/m^2	pound per square inch	psi	$lb/in.^2$
Time	second	s	(base unit)	second	s	(base unit)
Velocity (angular)	radian per second		rad/s	radian per second		rad/s
Velocity (linear)	meter per second		m/s	foot per second	fps	ft/s
Volume (liquids)	liter	L	$10^{-3}\ m^3$	gallon	gal.	$231\ in.^3$
Volume (solids)	cubic meter		m^3	cubic foot	cf	ft^3