时代教育·国外高校优秀教材精选

材 料 力 学

影印版·原书第8版

［美］ R. C. 希伯勒（R. C. Hibbeler） 编著

机 械 工 业 出 版 社

本书全面清晰地介绍了材料力学课程的理论和应用，讲解透彻、习题丰富。

本书内容包括应力、应变、材料的力学性能、轴向载荷、扭转、弯曲、横向剪切、组合载荷、应力转换、应变转换、梁和轴的设计、梁和轴的挠度、压杆的屈曲和能量法。

本书可作为普通高等院校材料力学双语教学的教材，也可供相关科研和工程技术人员参考。

图书在版编目（CIP）数据

材料力学：第8版：英文/（美）希伯勒（Hibbeler，R. C.）编著.
—影印本.—北京：机械工业出版社，2013.10
（时代教育：国外高校优秀教材精选）
ISBN 978-7-111-44480-0

Ⅰ.①材… Ⅱ.①希… Ⅲ.①材料力学—高等学校—教材—英文
Ⅳ.①TB301

中国版本图书馆 CIP 数据核字（2013）第 249290 号

机械工业出版社（北京市百万庄大街22号　邮政编码100037）
策划编辑：姜　凤　责任编辑：姜　凤
版式设计：霍永明　封面设计：张　静
责任印制：李　洋
三河市宏达印刷有限公司印刷
2013年11月第1版第1次印刷
205mm×235mm · 54.5印张 · 800千字
标准书号：ISBN 978-7-111-44480-0
定价：109.00元

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前　　言[⊖]

希伯勒（R. C. Hibbeler）编著、S. C. 范改编的《材料力学》（国际单位制，第8版），全面清晰地介绍了材料力学课程的理论和应用，讲解透彻、习题丰富，是当今世界上该领域最畅销的教材之一，享有盛誉。

本书提供足够数量的习题，并逐步增加难度，以便给学生提供所需的实际练习，培养学生分析问题和解决问题的能力。与第7版相比，本版有35%的新编习题、例题，大约550道，其中包括134种新增问题。这些新增习题涉及的领域包括航空航天、石油工程和生物力学等，展现了工程力学的现代应用，为学生在新兴工业领域工作打下基础。

例题将帮助学生夯实基础并理解问题背后的概念。习题具有多种可能解法，通过练习题，可以培养学生自己解决各种问题的能力。本版提供了新功能：在例题后设置了基本练习题。这为学生提供了概念的简单应用，确保他们在着手处理其他问题前，已经理解本章内容。

概念题是针对实际中遇到的真实问题。目的是培养和检验学生运用所学知识解决问题的能力。学生们将不断接触和掌握工程力学的最新应用。教师也得到了广泛的题目，可以从中选择、修改和添加内容，作为自己资料库中的新问题。在每一组概念题中，都力争按题目序号逐渐增加难度。除了每组第四个题目的答案，其他的答案都在书的后面给出。在题号前标有“*”的题目，是不提供答案的。即使材料性能的数据精度不足，本书的答案仍采用三位有效数字。虽然这可能是一种不适宜的做法，但全书连续、前后一致，可以让学生更好地验证自己的解决方案。标有“•”的习题则需要进行数值分析或运用计算机进行计算。

本书中很多图添加了矢量标注的逼真插图。这些插图形象生动地反映了工程的三维实际情况，也帮助学生形成形象思维，掌握问题背后的概念。全书有超过44张全新或更新的照片，用来解释如何将力学原理应用到实际工程中。

很多同行在多年的教学工作中，对本书提出了许多意见和建议。非常感谢他们的鼓励以及建设性的批评意见，在此我不再一一罗列。特别感谢：

Akthem Al-Manaseer，圣何塞州立大学

Yabin Liao，亚利桑那州立大学

Cliff Lissenden，宾夕法尼亚州立大学

Gregory M. Odegard，密歇根理工大学

John Oyler，匹茨堡大学

⊖ “前言”与“目录”由顾晓勤教授翻译整理。

Roy Xu，范德比尔特大学

Paul Ziehl，南卡罗来纳大学

有几个人要特别提及。在校对手稿和准备问题解答方面，老朋友和合作伙伴 Kai Beng Yap 给了我很大的帮助。也特别感谢劳雷尔技术综合出版服务公司的 Kurt Norlin。多年来，出版编辑 Rose Kernan 在出版过程中给与了帮助。我的妻子 Conny 和女儿 Mary Ann 参与了本书的文字输入和校对。

我也要感谢所有使用本书以前版本的学生，以及他们提出的修改意见和建议。

无论什么时候，如果你对本书的内容有任何意见或建议，请提出，我将不胜感激。

RUSSELL CHARLES HIBBELER

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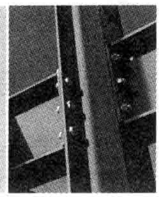
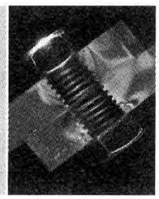
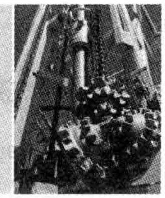
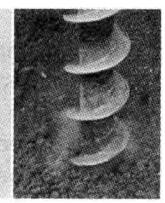
目　　录

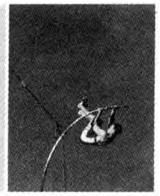
CONTENTS











12 Deflection of Beams and Shafts 569

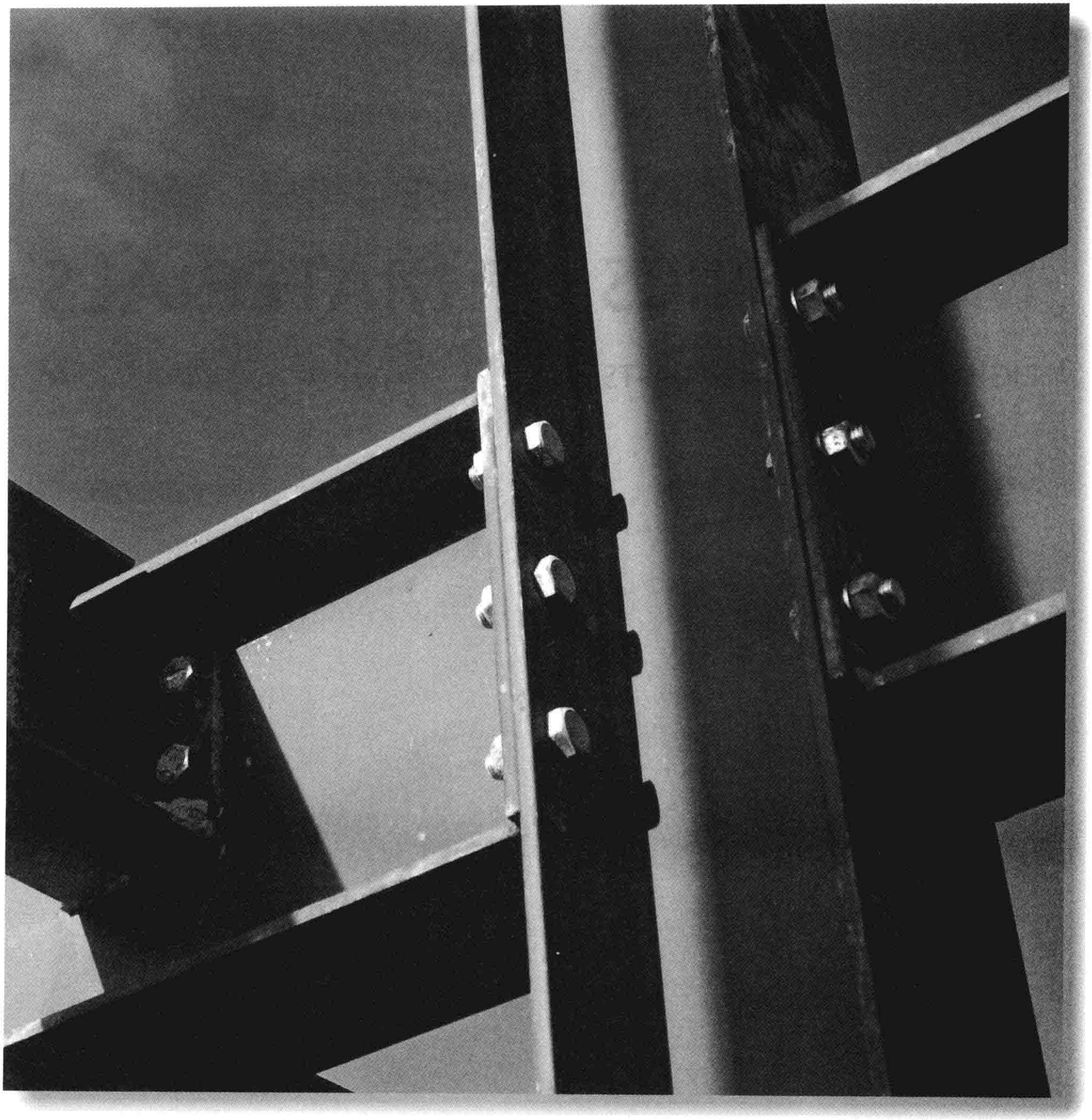
13 Buckling of Columns 657

14 Energy Methods 715

Appendices

MECHANICS OF MATERIALS

EIGHTH EDITION IN SI UNITS



The bolts used for the connections of this steel framework are subjected to stress. In this chapter we will discuss how engineers design these connections and their fasteners.

1

Stress

CHAPTER OBJECTIVES

In this chapter we will review some of the important principles of statics and show how they are used to determine the internal resultant loadings in a body. Afterwards the concepts of normal and shear stress will be introduced, and specific applications of the analysis and design of members subjected to an axial load or direct shear will be discussed.

Check out the Companion Website for the following video solution(s) that can be found in this chapter.

- Section 2
  Internal Forces Review, 2-D
- Section 2
  Internal Forces Review, 3-D
- Section 3
  Force Resultant Review
- Section 4
  Average Normal Stress
- Section 4, 5
  Average Normal and Shear Stress
- Section 6
  Allowable Stress
- Section 7
  Factor of Safety

1.1 Introduction

Mechanics of materials is a branch of mechanics that studies the internal effects of stress and strain in a solid body that is subjected to an external loading. Stress is associated with the strength of the material from which the body is made, while strain is a measure of the deformation of the body. In addition to this, mechanics of materials includes the study of the body's stability when a body such as a column is subjected to compressive loading. A thorough understanding of the fundamentals of this subject is of vital importance because many of the formulas and rules of design cited in engineering codes are based upon the principles of this subject.

1

Historical Development. The origin of mechanics of materials dates back to the beginning of the seventeenth century, when Galileo performed experiments to study the effects of loads on rods and beams made of various materials. However, at the beginning of the eighteenth century, experimental methods for testing materials were vastly improved, and at that time many experimental and theoretical studies in this subject were undertaken primarily in France, by such notables as Saint-Venant, Poisson, Lamé, and Navier.

Over the years, after many of the fundamental problems of mechanics of materials had been solved, it became necessary to use advanced mathematical and computer techniques to solve more complex problems. As a result, this subject expanded into other areas of mechanics, such as the *theory of elasticity* and the *theory of plasticity*. Research in these fields is ongoing, in order to meet the demands for solving more advanced problems in engineering.

1.2 Equilibrium of a Deformable Body

Since statics has an important role in both the development and application of mechanics of materials, it is very important to have a good grasp of its fundamentals. For this reason we will review some of the main principles of statics that will be used throughout the text.

External Loads. A body is subjected to only two types of external loads; namely, surface forces or body forces, Fig. 1–1.

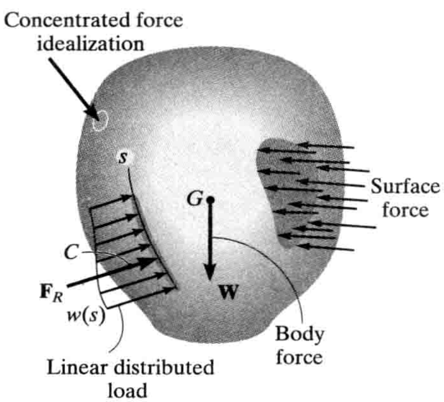


Fig. 1–1

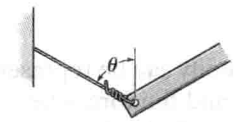
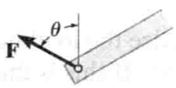
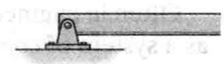
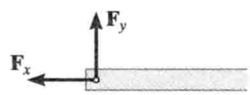
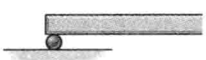
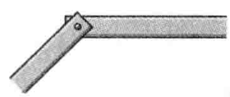
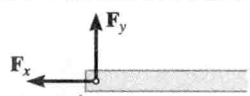
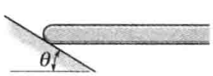
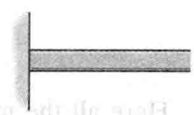
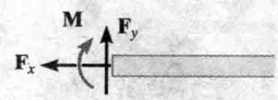
Surface Forces. ***Surface forces*** are caused by the direct contact of one body with the surface of another. In all cases these forces are distributed over the *area* of contact between the bodies. If this area is small in comparison with the total surface area of the body, then the surface force can be *idealized* as a single ***concentrated force***, which is applied to a *point* on the body. For example, the force of the ground on the wheels of a bicycle can be considered as a concentrated force. If the surface loading is applied along a narrow strip of area, the loading can be *idealized* as a ***linear distributed load***, $w(s)$. Here the loading is measured as having an intensity of force/length along the strip and is represented graphically by a series of arrows along the line s. ***The resultant force $\mathbf{F}_R$ of $w(s)$ is equivalent to the area under the distributed loading curve, and this resultant acts through the centroid C or geometric center of this area.*** The loading along the length of a beam is a typical example of where this idealization is often applied.

Body Forces. A ***body force*** is developed when one body exerts a force on another body without direct physical contact between the bodies. Examples include the effects caused by the earth's gravitation or its electromagnetic field. Although body forces affect each of the particles composing the body, these forces are normally represented by a single concentrated force acting on the body. In the case of gravitation, this force is called the ***weight*** of the body and acts through the body's center of gravity.

Support Reactions. The surface forces that develop at the supports or points of contact between bodies are called ***reactions***. For two-dimensional problems, i.e., bodies subjected to coplanar force systems, the supports most commonly encountered are shown in Table 1–1. Note carefully the symbol used to represent each support and the type of reactions it exerts on its contacting member. As a general rule, ***if the support prevents translation in a given direction, then a force must be developed on the member in that direction. Likewise, if rotation is prevented, a couple moment must be exerted on the member.*** For example, the roller support only prevents translation perpendicular or normal to the surface. Hence, the roller exerts a normal force **F** on the member at its point of contact. Since the member can freely rotate about the roller, a couple moment cannot be developed on the member.

Many machine elements are pin connected in order to enable free rotation at their connections. These supports exert a force on a member, but no moment.

TABLE 1–1

Type of connection	Reaction	Type of connection	Reaction
 Cable	 One unknown: F	 External pin	 Two unknowns: F_x, F_y
 Roller	 One unknown: F	 Internal pin	 Two unknowns: F_x, F_y
 Smooth support	 One unknown: F	 Fixed support	 Three unknowns: F_x, F_y, M

1

Equations of Equilibrium. Equilibrium of a body requires both a ***balance of forces***, to prevent the body from translating or having accelerated motion along a straight or curved path, and a ***balance of moments***, to prevent the body from rotating. These conditions can be expressed mathematically by two vector equations

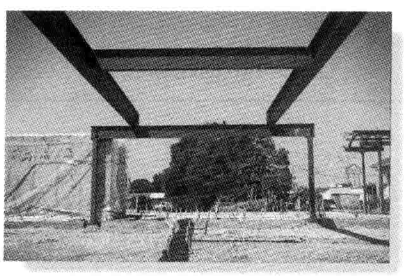
$$\begin{aligned} \Sigma \mathbf{F} &= 0 \\ \Sigma \mathbf{M}_O &= 0 \end{aligned} \qquad (1\text{–}1)$$

Here, $\Sigma \mathbf{F}$ represents the sum of all the forces acting on the body, and $\Sigma \mathbf{M}_O$ is the sum of the moments of all the forces about any point O either on or off the body. If an x, y, z coordinate system is established with the origin at point O, the force and moment vectors can be resolved into components along each coordinate axis and the above two equations can be written in scalar form as six equations, namely,

$$\begin{array}{lll} \Sigma F_x = 0 & \Sigma F_y = 0 & \Sigma F_z = 0 \\ \Sigma M_x = 0 & \Sigma M_y = 0 & \Sigma M_z = 0 \end{array} \qquad (1\text{–}2)$$

Often in engineering practice the loading on a body can be represented as a system of *coplanar forces*. If this is the case, and the forces lie in the x–y plane, then the conditions for equilibrium of the body can be specified with only three scalar equilibrium equations; that is,

$$\begin{aligned} \Sigma F_x &= 0 \\ \Sigma F_y &= 0 \\ \Sigma M_O &= 0 \end{aligned} \qquad (1\text{–}3)$$



In order to design the horizontal members of this building frame, it is first necessary to find the internal loadings at various points along their length.

Here all the moments are summed about point O and so they will be directed along the z axis.

Successful application of the equations of equilibrium requires complete specification of all the known and unknown forces that act *on* the body, and so ***the best way to account for all these forces is to draw the body's free-body diagram***.

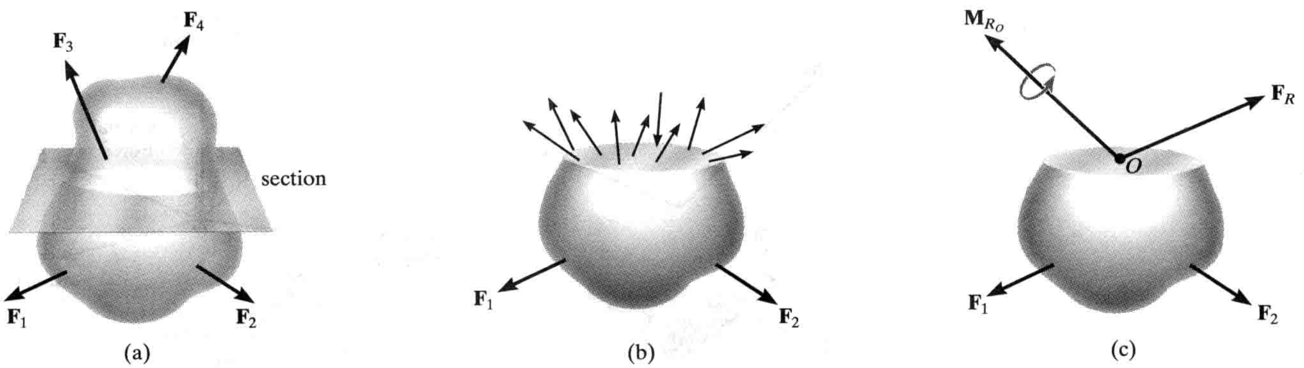


Fig. 1–2

Internal Resultant Loadings. In mechanics of materials, statics is primarily used to determine the resultant loadings that act within a body. For example, consider the body shown in Fig. 1–2*a*, which is held in equilibrium by the four external forces.* In order to obtain the internal loadings acting on a specific region within the body, it is necessary to pass an imaginary section or "cut" through the region where the internal loadings are to be determined. The two parts of the body are then separated, and a free-body diagram of one of the parts is drawn, Fig. 1–2*b*. Notice that there is actually a distribution of internal force acting on the "exposed" area of the section. These forces represent the effects of the material of the top part of the body acting on the adjacent material of the bottom part.

Although the exact distribution of this internal loading may be *unknown*, we can use the equations of equilibrium to relate the external forces on the bottom part of the body to the distribution's *resultant force and moment*, $\mathbf{F}_R$ and $\mathbf{M}_{R_O}$, *at any specific point O* on the sectioned area, Fig. 1–2*c*. It will be shown in later portions of the text that point O is most often chosen at the *centroid* of the sectioned area, and so we will always choose this location for O, unless otherwise stated. Also, if a member is long and slender, as in the case of a rod or beam, the section to be considered is generally taken *perpendicular* to the longitudinal axis of the member. This section is referred to as the ***cross section***.

*The body's weight is not shown, since it is assumed to be quite small, and therefore negligible compared with the other loads.

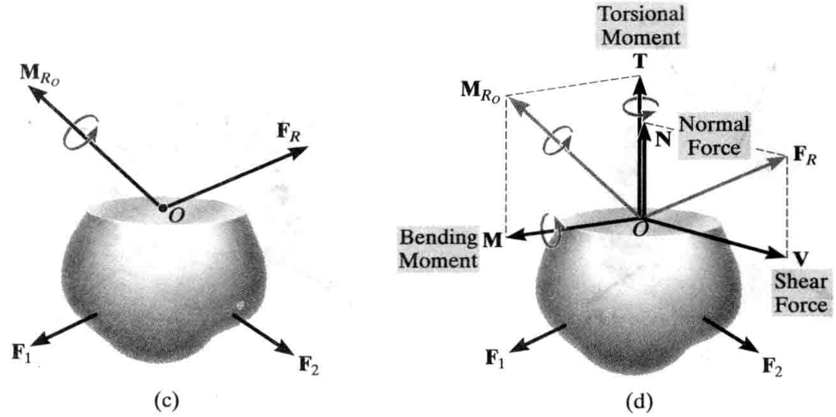


Fig. 1–2 (cont.)

Three Dimensions. Later in this text we will show how to relate the resultant loadings, $\mathbf{F}_R$ and $\mathbf{M}_{R_O}$, to the *distribution of force* on the sectioned area, and thereby develop equations that can be used for analysis and design. To do this, however, the components of $\mathbf{F}_R$ and $\mathbf{M}_{R_O}$ acting both normal and perpendicular to the sectioned area must be considered, Fig. 1–2*d*. Four different types of resultant loadings can then be defined as follows:

Normal force, N. This force acts perpendicular to the area. It is developed whenever the external loads tend to push or pull on the two segments of the body.

Shear force, V. The shear force lies in the plane of the area and it is developed when the external loads tend to cause the two segments of the body to slide over one another.

Torsional moment or torque, T. This effect is developed when the external loads tend to twist one segment of the body with respect to the other about an axis perpendicular to the area.

Bending moment, M. The bending moment is caused by the external loads that tend to bend the body about an axis lying within the plane of the area.

In this text, note that graphical representation of a moment or torque is shown in three dimensions as a vector with an associated curl. By the *right-hand rule*, the thumb gives the arrowhead sense of this vector and the fingers or curl indicate the tendency for rotation (twisting or bending).