Chapter 1

Introduction

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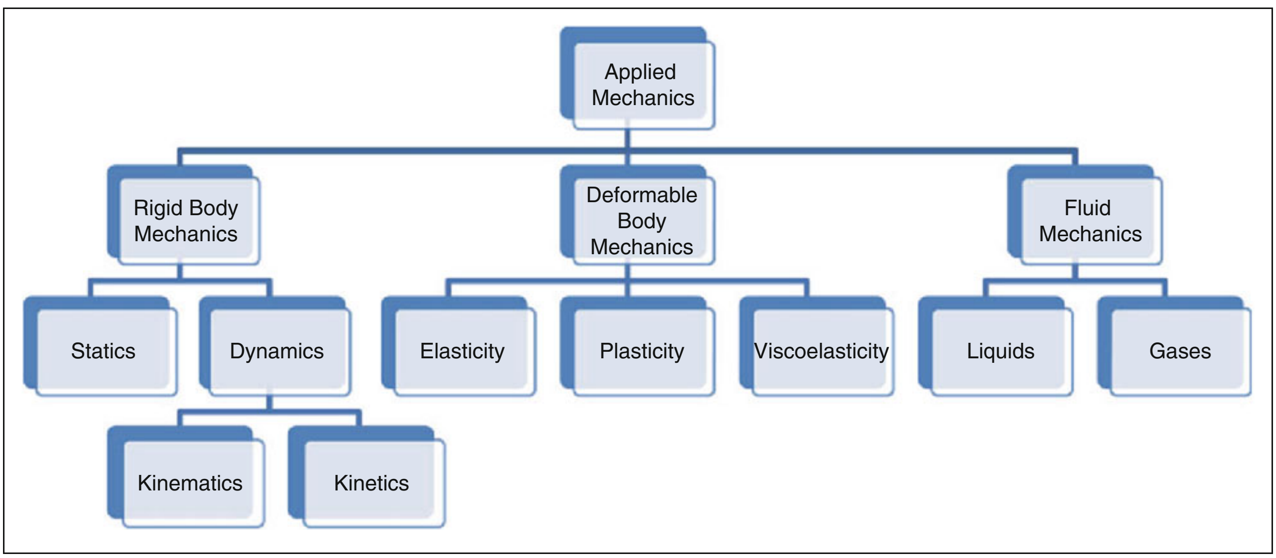
1.1 Mechanics

Mechanics is a branch of physics that is concerned with the motion and deformation of bodies that are acted on by mechanical disturbances called forces. Mechanics is the oldest of all physical sciences, dating back to the times of Archimedes (287–212 BC). Galileo (1564–1642) and Newton (1642–1727) were the most prominent contributors to this field. Galileo made the first fundamental analyses and experiments in dynamics, and Newton formulated the laws of motion and gravity.

Engineering mechanics or *applied mechanics* is the science of applying the principles of mechanics. Applied mechanics is concerned with both the analysis and design of mechanical systems. The broad field of applied mechanics can be divided into three main parts, as illustrated in Table 1.1.

Table 1.1 *Classification of applied mechanics*



In general, a material can be categorized as either a solid or fluid. Solid materials can be rigid or deformable. A *rigid body* is one that cannot be deformed. In reality, every object or material does undergo deformation to some extent when acted upon by external forces. In some cases the amount of deformation is so small that it does not affect the desired analysis. In such cases, it is preferable to consider the body as rigid and carry out the analysis with relatively simple computations.

Statics is the study of forces on rigid bodies at rest or moving with a constant velocity. *Dynamics* deals with bodies in motion. *Kinematics* is a branch of dynamics that deals with the geometry and time-dependent aspects of motion without considering the forces causing the motion. *Kinetics* is based on kinematics, and it includes the effects of forces and masses in the analysis.

Statics and dynamics are devoted primarily to the study of the external effects of forces on rigid bodies, bodies for which the deformation (change in shape) can be neglected. On the other hand, the *mechanics of deformable bodies* deals with the relations between externally applied loads and their internal effects on bodies. This field of applied mechanics does not assume that the bodies of interest are rigid, but considers the true nature of their material properties. The mechanics of deformable bodies has strong ties with the field of material science which deals with the atomic and molecular structure of materials. The principles of deformable body mechanics have important applications in the design of structures and machine elements. In general, analyses in deformable body mechanics are more complex as compared to the analyses required in rigid body mechanics.

The mechanics of deformable bodies is the field that is concerned with the deformability of objects. *Deformable body mechanics* is subdivided into the mechanics of elastic, plastic, and viscoelastic materials, respectively. An *elastic* body is defined as one in which all deformations are recoverable upon removal of external forces. This feature of some materials can easily be visualized by observing a spring or a rubber band. If you gently stretch (deform) a spring and then release it (remove the applied force), it will resume its original (undeformed) size and shape. A *plastic* body, on the other hand, undergoes permanent (unrecoverable) deformations. One can observe this behavior again by using a spring. Apply a large force on a spring so as to stretch the spring extensively, and then release it. The spring will bounce back, but there may be an increase in its length. This increase illustrates the extent of plastic deformation in the spring. Note that depending on the extent and duration of applied forces, a material may exhibit elastic or elastoplastic behavior as in the case of the spring.

To explain viscoelasticity, we must first define what is known as a *fluid*. In general, materials are classified as either solid or fluid. When an external force is applied to a solid body, the body will deform to a certain extent. The continuous application of the same force will not necessarily deform the solid body continuously. On the other hand, a continuously applied force on a fluid body will cause a continuous deformation (flow). *Viscosity* is a fluid property which is a quantitative measure of resistance to flow. In nature there are some materials that have both fluid and solid properties. The term *viscoelastic* is used to refer to the mechanical properties of such materials. Many biological materials exhibit viscoelastic properties.

The third part of applied mechanics is *fluid mechanics*. This includes the *mechanics of liquids* and the *mechanics of gases*.

Note that the distinctions between the various areas of applied mechanics are not sharp. For example, viscoelasticity simultaneously utilizes the principles of fluid and solid mechanics.

1.2 Biomechanics

In general, biomechanics is concerned with the application of classical mechanics to various biological problems. *Biomechanics* combines the field of engineering mechanics with the fields of biology and physiology. Basically, biomechanics is concerned with the human body. In biomechanics, the principles of mechanics are applied to the conception, design, development, and analysis of equipment and systems in biology and medicine. In essence, biomechanics is a multidisciplinary science concerned with the application of mechanical principles to the human body in motion and at rest.

Although biomechanics is a relatively young and dynamic field, its history can be traced back to the fifteenth century, when Leonardo da Vinci (1452–1519) noted the significance of mechanics in his biological studies. As a result of contributions of researchers in the fields of biology, medicine, basic sciences, and engineering, the interdisciplinary field of biomechanics has been growing steadily in the last five decades.

The development of the field of biomechanics has improved our understanding of many things, including normal and pathological situations, mechanics of neuromuscular control, mechanics of blood flow in the microcirculation, mechanics of air flow in the lung, and mechanics of growth and form. It has contributed to the development of medical diagnostic and treatment procedures. It has provided the means for designing and manufacturing medical equipment, devices, and instruments, assistive technology devices for people with disabilities, and artificial replacements and implants. It has suggested the means for improving human performance in the workplace and in athletic competition.

Different aspects of biomechanics utilize different concepts and methods of applied mechanics. For example, the principles of statics are applied to determine the magnitude and nature of forces involved in various joints and muscles of the musculoskeletal system. The principles of dynamics are utilized for motion description and have many applications in sports mechanics. The principles of the mechanics of deformable bodies provide the necessary tools for developing the field and constitutive equations for biological materials and systems, which in turn are used to evaluate their functional behavior under different conditions. The principles of fluid mechanics are used to investigate the blood flow in the human circulatory system and air flow in the lung.

It is the aim of this textbook to expose the reader to the principles and applications of biomechanics. For this purpose, the basic tools and principles will first be introduced. Next, systematic and comprehensive applications of these principles will be carried out with many solved example problems. Attention will be focused on the applications of statics, dynamics, and the mechanics of deformable bodies (i.e., solid mechanics). A limited study of fluid mechanics and its applications in biomechanics will be provided as well.

1.3 Basic Concepts

Engineering mechanics is based on Newtonian mechanics in which the basic concepts are length, time, and mass. These are absolute concepts because they are independent of each other. *Length* is a concept for describing size quantitatively. *Time* is a concept for ordering the flow of events. *Mass* is the property of all matter and is the quantitative measure of inertia. *Inertia* is the resistance to the change in motion of matter. Inertia can also be defined as the ability of a body to maintain its state of rest or uniform motion.

Other important concepts in mechanics are not absolute but derived from the basic concepts. These include force, moment or torque, velocity, acceleration, work, energy, power, impulse, momentum, stress, and strain. *Force* can be defined in many ways, such as mechanical disturbance or load. Force is the action of one body on another. It is the force applied on a body which causes the body to move, deform, or both. *Moment* or *torque* is the quantitative measure of the rotational, bending or twisting action of a force applied on a body. *Velocity* is defined as the time rate of change of position. The time rate of increase of velocity, on the other hand, is termed *acceleration*. Detailed descriptions of these and other relevant concepts will be provided in subsequent chapters.

1.4 Newton's Laws

The entire field of mechanics rests on a few basic laws. Among these, the laws of mechanics introduced by Sir Isaac Newton form the basis for analyses in statics and dynamics.

Newton's first law states that a body that is originally at rest will remain at rest, or a body in motion will move in a straight line with constant velocity, if the net force acting upon the body is zero. In analyzing this law, we must pay extra attention to a number of key words. The term "rest" implies no motion. For example, a book lying on a desk is said to be at rest. To be able to explain the concept of "net force" fully, we need to introduce vector algebra (see Chap. 2). The net force simply refers to the combined effect of all forces acting on a body. If the net force acting on a body is zero, it does not necessarily mean that there are no forces acting on the body. For example, there may be two equal and opposite forces applied on a body so that the combined effect of the two forces on the body is zero, assuming that the body is rigid. Note that if a body is either at rest or moving in a straight line with a constant velocity, then the body is said to be in *equilibrium*. Therefore, the first law states that if the net force acting on a body is zero, then the body is in equilibrium.

Newton's second law states that a body with a net force acting on it will accelerate in the direction of that force, and that the magnitude of the acceleration will be directly proportional to the magnitude of the net force and inversely proportional to the mass of the body. The important terms in the statement of the second law are "magnitude" and "direction," and they will be explained in detail in Chap. 2, within the context of vector algebra.

Newton's third law states that to every action there is always an equal reaction, and that the forces of action and reaction between interacting bodies are equal in magnitude, opposite in direction, and have the same line of action. This law can be simplified by saying that if you push a body, the body will push you back. This law has important applications in constructing *free-body diagrams* of components constituting large systems. The free-body diagram of a component of a structure is one in which the surrounding parts of the structure are replaced by equivalent forces. It is an effective aid to study the forces involved in the structure.

Newton's laws will be explained in detail in subsequent chapters, and they will be utilized extensively throughout this text.

1.5 Dimensional Analysis

The term "dimension" has several uses in mechanics. It is used to describe space, as for example while referring to one-dimensional, two-dimensional, or three-dimensional situations. Dimension is also used to denote the nature of quantities. Every measurable quantity has a *dimension* and a *unit* associated with it. Dimension is a general description of a quantity, whereas unit is associated with a system of units (see Sect. 1.6). Whether a distance is measured in meters or feet, it is a distance. We say that its dimension is "length." Whether a flow of events is measured in seconds, minutes, hours, or even days, it is a point of time when a specific event began and then ended. So we say its dimension is "time."

There are two sets of dimensions. *Primary*, or *basic*, *dimensions* are those associated with the basic concepts of mechanics. In this text, we shall use capital letters L, T, and M to specify the primary dimensions length, time, and mass, respectively. We shall use square brackets to denote the dimensions of physical quantities. The basic dimensions are:

$$[\text{LENGTH}] = L$$
$$[\text{TIME}] = T$$
$$[\text{MASS}] = M$$

Secondary dimensions are associated with dependent concepts that are derived from basic concepts. For example, the area of a rectangle can be calculated by multiplying its width and length, both of which have the dimension of length. Therefore, the dimension of area is:

$$[\text{AREA}] = [\text{LENGTH}][\text{LENGTH}] = LL = L^2$$

By definition, velocity is the time rate of change of relative position. Change of the relative position is measured in terms of length units. Therefore, the dimension of velocity is:

$$[\text{VELOCITY}] = \frac{[\text{POSITION}]}{[\text{TIME}]} = \frac{L}{T}$$

The secondary dimensional quantities are established as a consequence of certain natural laws. If we know the definition of a physical quantity, we can easily determine the dimension of that quantity in terms of basic dimensions. If the dimension of a physical quantity is known, then the units of that quantity in different systems of units can easily be determined as well. Furthermore, the validity of an equation relating a number of physical quantities can be verified by analyzing the dimensions of terms forming the equation or formula. In this regard, the *law of dimensional homogeneity* imposes restrictions on the formulation of such relations. To explain this law, consider the following arbitrary equation:

$$Z = aX + bY + c$$

For this equation to be dimensionally homogeneous, every grouping in the equation must have the same dimensional representation. In other words, if Z refers to a quantity whose dimension is length, then products aX and bY, and quantity

c must all have the dimension of length. The numerical equality between both sides of the equation must also be maintained for all systems of units.

1.6 Systems of Units

There have been a number of different systems of units adopted in different parts of the world. For example, there is the British gravitational or foot–pound–second system, the Gaussian (metric absolute) or centimeter–gram–second (c–g–s) system, and the metric gravitational or meter–kilogram–second (mks) system. The lack of a universal standard in units of measure often causes confusion.

In 1960, an International Conference on Weights and Measures was held to bring an order to the confusion surrounding the units of measure. Based on the metric system, this conference adopted a system called *Le Système International d'Unités* in French, which is abbreviated as SI. In English, it is known as the International System of Units. Today, nearly the entire world is either using this modernized metric system or committed to its adoption. In the International System of Units, the units of length, time, and mass are meter (m), second (s), and kilogram (kg), respectively.

The units of measure of these fundamental concepts in three different systems of units are listed in Table 1.2. Throughout this text, we shall use the International System of Units. Other units will be defined for informational purposes.

Table 1.2 *Units of fundamental quantities of mechanics*

System	Length	Mass	Time
SI	Meter (m)	Kilogram (kg)	Second (s)
c–g–s	Centimeter (cm)	Gram (g)	Second (s)
British	Foot (ft)	Slug (slug)	Second (s)

Once the units of measure for the primary concepts are agreed upon, the units of measure for the derived concepts can easily be determined provided that the dimensional relationship between the basic and derived quantities is known. All that is required is replacing the dimensional representation of length, mass, and time with their appropriate units. For example, the dimension of force is ML/T^2. Therefore, according to the International System of Units, force has the unit of kg m/s^2, which is also known as Newton (N). Similarly, the unit of force is lb ft/s^2 in the British system of units, and is g cm/s^2

or dyne (dyn) in the metric absolute or c–g–s system. Table 1.3 lists the dimensional representations of some of the derived quantities and their units in the International System of Units.

Table 1.3 *Dimensions and units of selected quantities in SI*

Quantity	Dimension	SI unit	Special name
Area	L^2	m^2	
Volume	L^3	m^3	
Velocity	L/T	m/s	
Acceleration	L/T^2	m/s^2	
Force	$M \cdot L/T^2$	kg m/s^2	Newton (N)
Pressure and stress	$M/L \cdot T^2$	N/m^2	Pascal (Pa)
Moment (Torque)	$M \cdot L^2/T^2$	Nm	
Work and energy	$M \cdot L^2/T^2$	Nm	Joule (J)
Power	$M \cdot L^2/T^3$	J/s	Watt (W)

Note that "kilogram" is the unit of mass in SI. For example, consider a 60 kg object. The weight of the same object in SI is $(60\,\text{kg}) \times (9.8\,\text{m/s}^2) = 588\,\text{N}$, the factor 9.8 m/s^2 being the magnitude of the gravitational acceleration.

In addition to the primary and secondary units that are associated with the basic and derived concepts in mechanics, there are *supplementary units* such as plane angle and temperature. The common measure of an angle is degree (°). Three hundred and sixty degrees is equal to one revolution (rev) or 2π radians (rad), where $\pi = 3.1416$. The SI unit of temperature is Kelvin (K). However, degree Celsius (°C) is more commonly used. The British unit of temperature is degree Fahrenheit (°F).

It should be noted that in most cases, a number has a meaning only if the correct unit is displayed with it. In performing calculations, the ideal method is to show the correct units with each number throughout the solution of equations. This approach helps in detecting conceptual errors and eliminates the need for determining the unit of the calculated quantity separately. Another important aspect of using units is consistency. One must not use the units of one system for some quantities and the units of another system for other quantities while carrying out calculations.

1.7 Conversion of Units

The International System of Units is a revised version of the metric system which is based on the decimal system. Table 1.4 lists the SI multiplication factors and corresponding prefixes.

Table 1.4 *SI multiplication factors and prefixes*

Multiplication factor	SI prefix	SI symbol
1,000,000,000 = 10^9	Giga	G
1,000,000 = 10^6	Mega	M
1000 = 10^3	Kilo	k
100 = 10^2	Hector	h
10 = 10	Deka	da
.1 = 10^{-1}	Deci	d
.01 = 10^{-2}	Centi	c
.001 = 10^{-3}	Milli	m
.000,001 = 10^{-6}	Micro	μ
.000,000,001 = 10^{-9}	Nano	n
.000,000,000,001 = 10^{-12}	Pico	p

Table 1.5 lists factors needed to convert quantities expressed in British and metric systems to corresponding units in SI.

Table 1.5 *Conversion of units*

Length	1 centimeter (cm) = 0.01 meter (m) = 0.3937 inch (in.) 1 in. = 2.54 cm = 0.0254 m 1 foot (ft) = 30.48 cm—0.3048 m 1 m = 3.28 ft = 39.37 in. 1 yard (yd) = 0.9144 m = 3 ft 1 mile = 1609 m = 1.609 kilometer (km) = 5280 ft 1 km = 0.6214 mile
Time	1 minute (min) = 60 seconds (s) 1 hour (h) = 60 min = 3600 s 1 day = 24 h = 1440 min = 86,400 s
Area	1 cm^2 = 0.155 $in.^2$ 1 $in.^2$ = 6.452 cm^2 1 m^2 = 10.763 ft^2 1 ft^2 = 0.0929 m^2

(*continued*)

Table 1.5 (continued)

Mass	1 pound mass (lbm) = 0.4536 kilogram (kg) 1 kg = 2.2 lbm = 0.0685 slug 1 slug = 14.59 kg = 32.098 lbm
Force	1 kilogram force (kgf) = 9.807 Newton (N) 1 pound force (lbf) = 4.448 N 1 N = 0.2248 lbf 1 dyne (dyn) = 10^{-5} N 1 N = 10^5 dyn
Pressure and stress	1 N/m^2 = 1 Pascal (Pa) = 0.000145 lbf/in.^{2} (psi) 1 psi = 6895 Pa 1 lbf/ft^2 (psf) = 592,966 Pa 1 dyn/cm^2 = 0.1 Pa
Moment (Torque)	1 Nm = 10^7 dyn cm = 0.7376 lbf ft 1 dyn/cm = 10^{-7} Nm 1 lbf ft = 1.356 Nm
Work and energy	1 Nm = 1 Joule (J) = 10^7 erg 1 J = 0.7376 lbf ft 1 lbf ft = 1.356 J
Power	1 kg m^2/s^3 = 1 J/S = 1 Watt (W) 1 horsepower (hp) = 550 lbf ft/s = 746 W 1 lbf ft/s = 1.356 W 1 W = 0.737 lbf ft/s
Plane angle	1 degree (°) = π/180 radian (rad) 1 revolution (rev) = 360° 1 rev = 2π rad = 6.283 rad 1 rad = 57.297° 1° = 0.0175 rad
Temperature	°C = 273.2 K °C = 5/9 (−32 °F) °F = 9/5 (+32 °C)

1.8 Mathematics

The applications of biomechanics require some knowledge of mathematics. These include simple geometry, properties of the right triangle, basic algebra, differentiation, and integration. The appendices that follow the last chapter contain a summary of the mathematical tools and techniques needed to carry out the calculations in this book. The reader may find it useful to examine them now, and review them later when those concepts are needed. In subsequent chapters throughout the text, the mathematics required will be reviewed and the corresponding appendix will be indicated.

During the formulation of the problems, we shall use Greek letters as well as the letters of the Latin alphabet. Greek letters will be used, for example, to refer to angles. The Greek alphabet is provided in Table 1.6 for quick reference.

Table 1.6 *Greek alphabet*

Alpha	A	α	Iota	I	ι	Rho	P	ρ
Beta	B	β	Kappa	K	k	Sigma	Σ	σ
Gamma	Γ	γ	Lambda	Λ	λ	Tau	T	τ
Delta	Δ	δ	Mu	M	μ	Upsilon	Y	υ
Epsilon	E	ε	Nu	N	ν	Phi	Φ	υ
Zeta	Z	ζ	Xi	Ξ	ξ	Chi	X	χ
Eta	H	η	Omicron	O	o	Psi	Ψ	ψ
Theta	Θ	θ	Pi	Π	π	Omega	Ω	ω

1.9 Scalars and Vectors

In mechanics, two kinds of quantities are distinguished. A *scalar* quantity, such as mass, temperature, work, and energy, has magnitude only. A *vector* quantity, such as force, velocity, and acceleration, has both a magnitude and a direction. Unlike scalars, vector quantities add according to the rules of vector algebra. Vector algebra will be covered in detail in Chap. 2.

1.10 Modeling and Approximations

One needs to make certain assumptions to simplify complex systems and problems so as to achieve analytical solutions. The complete model is the one that includes the effects of all parts constituting a system. However, the more detailed the model, the more difficult the formulation and solution of the problem. It is not always possible and in some cases it may not be necessary to include every detail in the analysis. For example, during most human activities, there is more than one muscle group activated at a time. If the task is to analyze the forces involved in the joints and muscles during a particular human activity, the best approach is to predict which muscle group is the most active and set up a model that neglects all other muscle groups. As we shall see in the following chapters, bone is a deformable body. If the forces involved are relatively small, then the bone can be treated as a rigid body. This approach may help to reduce the complexity of the problem under consideration.

In general, it is always best to begin with a simple basic model that represents the system. Gradually, the model can be expanded on the basis of experience gained and the results obtained from simpler models. The guiding principle is to make simplifications that are consistent with the required accuracy of the results. In this way, the researcher can set up a model that is simple enough to analyze and exhibit satisfactorily the phenomena under consideration. The more we learn, the more detailed our analysis can become.

1.11 Generalized Procedure

The general method of solving problems in biomechanics may be outlined as follows:

1. Select the system of interest.
2. Postulate the characteristics of the system.
3. Simplify the system by making proper approximations. Explicitly state important assumptions.
4. Form an analogy between the human body parts and basic mechanical elements.
5. Construct a mechanical model of the system.
6. Apply principles of mechanics to formulate the problem.
7. Solve the problem for the unknowns.
8. Compare the results with the behavior of the actual system. This may involve tests and experiments.
9. If satisfactory agreement is not achieved, steps 3 through 7 must be repeated by considering different assumptions and a new model of the system.

1.12 Scope of the Text

Courses in biomechanics are taught within a wide variety of academic programs to students with quite different backgrounds and different levels of preparation coming from various disciplines of engineering as well as other academic disciplines. This text is prepared to provide a teaching and learning tool primarily to health care professionals who are seeking a graduate degree in biomechanics but have limited backgrounds in calculus, physics, and engineering mechanics.

This text can also be a useful reference for undergraduate biomedical, biomechanical, or bioengineering programs.

This text is divided into three parts. The first part (Chaps. 1 through 5, and Appendices A and B) will introduce the basic concepts of mechanics including force and moment vectors, provide the mathematical tools (geometry, algebra, and vector algebra) so that complete definitions of these concepts can be given, explain the procedure for analyzing the systems at "static equilibrium," and apply this procedure to analyze simple mechanical systems and the forces involved at various muscles and joints of the human musculoskeletal system. It should be noted here that the topics covered in the first part of this text are prerequisites for both parts two and three.

The second part of the text (Chaps. 6 through 11) is devoted to "dynamic" analyses. The concepts introduced in the second part are position, velocity and acceleration vectors, work, energy, power, impulse, and momentum. Also provided in the second part are the techniques for kinetic and kinematic analyses of systems undergoing translational and rotational motions. These techniques are applied for human motion analyses of various sports activities.

The last section of the text (Chaps. 12 through 15) provides the techniques for analyzing the "deformation" characteristics of materials under different load conditions. For this purpose, the concepts of stress and strain are defined. Classifications of materials based on their stress–strain diagrams are given. The concepts of elasticity, plasticity, and viscoelasticity are also introduced and explained. Topics such as torsion, bending, fatigue, endurance, and factors affecting the strength of materials are provided. The emphasis is placed upon applications to orthopaedic biomechanics.

1.13 Notation

While preparing this text, special attention was given to the consistent use of notation. Important terms are italicized where they are defined or described (such as, *force* is defined as load or mechanical disturbance). Symbols for quantities are also italicized (for example, m for mass). Units are not italicized (for example, kg for kilogram). Underlined letters are used to refer to vector quantities (for example, force vector $\underline{F}$). Sections and subsections marked with a star (*) are considered optional. In other words, the reader can omit a section or subsection marked with a star without losing the continuity of the topics covered in the text.

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[1] We believe that this text is a self-sufficient teaching and learning tool. While preparing it, we utilized the information provided from many sources, some of which are listed below. Note, however, that it is not our intention to promote these publications, or to suggest that these are the only texts available on the subject matter. The field of biomechanics has been growing very rapidly. There are many other sources of readily available information, including scientific journals presenting peer-reviewed research articles in biomechanics.

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V. Biomechanics Societies

Bulgarian Society of Biomechanics: http://www.imbm.bas.bg/biomechanics/index.php/societies

Czech Society of Biomechanics: http://www.csbiomech.cz/index.php/en/

Danish Society of Biomechanics: http://www.danskbiomekaniskselskab.dk/

European Society of Biomechanics: http://esbiomech.org/

French Society of Biomechanics: http://www.biomecanique.org/

Hellenic Society of Biomechanics: http://www.elembio.gr/index.php/el/

International Society of Biomechanics: https://isbweb.org/

International Society of Biomechanics in Sports: http://www.isbs.org/

Polish Society of Biomechanics: http://www.biomechanics.pl/

Portuguese Society of Biomechanics: http://www.spbiomecanica.com/

The British Association of Sport and Exercise Sciences: http://www.bases.org.uk/

VI. Biomechanics Journals

Applied Bionics and Biomechanics: http://www.hindawi.com/journals/abb/
Clinical Biomechanics: http://www.clinbiomech.com/
International Journal of Experimental and Computational Biomechanics: http://www.journal-data.com/journal/international-journal-of-experimental-and-computational-biomechanics.html
Journal of Biomechanics: http://www.jbiomech.com/
Journal of Applied Biomechanics: http://journals.humankinetics.com/about-jab
Journal of Biomechanical Engineering: http://biomechanical.asmedigitalcollection.asme.org/journal.aspx
Journal of Biomechanical Science and Engineering: http://jbse.org/
Journal of Dental Biomechanics: http://www.journal-data.com/journal/journal-of-dental-biomechanics.html
Sports Biomechanics: http://www.isbs.org/journal.html

VII. Biomechanics-Related Graduate Programs in the United States[2]

Boston University. Department of Biomedical Engineering: http://www.bu.edu/dbin/bme/
University of California Berkeley. Department of Bioengineering: http://bioegrad.berkeley.edu/
Carnegie Mellon. Department of Biomedical Engineering: http://www.bme.cmu.edu/
Columbia University. Department of Biomedical Engineering: http://www.bme.columbia.edu/index.html
Cornell University. Department of Biomedical Engineering: http://www.bme.cornell.edu/
Duke University. Biomedical Engineering: http://www.bme.duke.edu/grads/
Harvard University. School of Public Health. Occupational Biomechanics and Ergonomics Laboratory: http://www.hsph.harvard.edu/ergonomics/
Johns Hopkins University. The Whitaker Institute. Department of Biomedical Engineering: http://www.bme.jhu.edu/
University of Michigan. Center for Ergonomics: http://www.engin.umich.edu/dept/ioe/C4E/
MIT. Center for Biomedical Engineering: http://web.mit.edu/afs/athena.mit.edu/org/c/cbe/www/
University of North Carolina at Chapel Hill. Biomedical Engineering: http://www.bme.unc.edu/academics/grad.html
New Jersey Institute of Technology. Department of Biomedical Engineering: http://biomedical.njit.edu/index.php
New York University. Graduate School of Arts and Science. Environmental Health Sciences-Ergonomics and Biomechanics Program: http://oioc.med.nyu.edu/education/masters-program
Ohio State University. Department of Biomedical Engineering: http://www.bme.ohio-state.edu/bmeweb3/
Stanford University. Department of Bioengineering: http://bioengineering.stanford.edu/education/ms.html
Syracuse University. Department of Biomedical Engineering: http://www.lcs.syr.edu/academic/biochem_engineering/index.aspx
Yale University. Department of Biomedical Engineering: http://www.eng.yale.edu/content/DPBiomedicalEngineering.asp

[2] For complete list of biomechanics-related Graduate Programs in the United States, visit the website of The American Society of Biomechanics, http://www.asbweb.org/.