

Chapter 1

What Is Biomechanics?

Chapter Overview

The study of human movement, kinesiology, encompasses multiple subdisciplines. Biomechanics is one of the subdisciplines where biological systems are studied from a mechanical perspective. Mechanics is subdivided into kinematics and kinetics. Kinematics is descriptive in nature and explains both static and dynamic motion in terms of displacement, velocity, and acceleration. Kinetics explains the underlying forces that cause and/or result from both static and dynamic motion.

Chapter One gives an overview of the relevant questions being answered by today's biomechanist. A basic understanding of mechanical concepts is essential for a practitioner as well as a researcher. Basic knowledge of the principles of biomechanics is very essential for physical educators, athletic trainers, physical and occupational therapists, coaches, personal trainers, and physicians to be successful.

Analysis of human movement may be either quantitative or qualitative. Both of which are important to the practitioner. The chapter provides an introduction to qualitative analysis and a systematic approach for solving formal quantitative problems.

Teaching Tips

Develop strategies to help students with math phobia. Determine what resources are available, and encourage students early in the term to use those resources. Ask students to solve problems and exercises in groups. This will help students who find it difficult to solve such problems and exercises on their own. In a diverse group, it is important to use examples applicable to specific situations (sport, dance, rehabilitation, etc.) and/or examples applicable to activities common to everyone (walking, climbing stairs, etc.).

Assessment Techniques

1. Goal Ranking and Matching

Ask students to identify two or three learning goals they hope to achieve by participating in the class or lab. Then, ask them to rank the goals according to their relative importance.

After sharing their goals with the instructor, the students will learn what the instructor hopes to achieve so a comparison can be made. In an elective course, this exercise may help a student determine whether to opt out of the course. In a required course, the instructor may use this information to tailor the class to a specific population. For example, physical therapy students in a biomechanics class may have different needs and expectations than students preparing to coach. [Angelo, T.A. & Cross, P.K. (1993). *Classroom Assessment Techniques* (2nd ed.). San Francisco: Jossey-Bass.]

2. **YouTube**

The Internet provides a massive source of content that can be used to supplement the course. Often, students will comprehend a concept much more quickly if they can see a demonstration. YouTube is an excellent source of videos related to many of the biomechanics concepts presented in the text. A couple of samples will be provided for each chapter. As the instructor, you can determine how to best use the videos. For example, you might find applicable videos and assign them to students for outside viewing or as a part of their homework. The videos can also be shown during class, to complement the lecture or discussion. Alternatively, you can assign relevant concepts and challenge the students to find appropriate and accurate videos to share with the class. Like other content that is not peer reviewed, the videos posted on YouTube may or may not be accurate. However, errors can also present “teaching moments.”

The following are the links to two concepts presented in Chapter 1.

Biomechanics

http://www.youtube.com/watch?v=x6y70_Hn9SY

Metric System and Standard Measurement Systems

http://www.youtube.com/watch?v=DQPQ_q59xyw&feature=related

The links are provided as examples of videos that can be used to supplement the content of the course. The authors and publishers do not own or endorse the videos or guarantee the links will remain active. If these samples are not active, accurate, or appropriate for your class, please find other samples that will work better for you.

Labs on a Budget

The inclusion of several laboratory experiences is recommended for all undergraduate biomechanics classes. In the absence of expensive research equipment, there are still many items that can be used to help students experiment with the concepts. The authors and publishers do

not own or endorse specific products. However, in selected instances, specific vendor examples are provided. Equipment ideas will be presented in Chapters 5, 10, and 12.

There are many examples of biomechanics and/or physics labs online. Many use very low-cost equipment that are still effective in helping students learn the concepts. The following is an example of a website that has some low-cost experiments relevant to the biomechanics concepts presented in the text: <http://www.physicsclassroom.com/lab/>. It also provides links to other websites related to labs. The following is an example of a vendor's website that provides low-cost lab equipment: <http://www.arborsci.com/>.

Related Weblinks

- www.acsm.org (American College of Sports Medicine)
- <http://www.asbweb.org/> (American Society of Biomechanics)

Solutions to Selected Introductory Problems

8. Solve for x in each of the equations below. Refer to Appendix A for help if necessary.

a. $x = 5^3$
 $x = 5 \times 5 \times 5 = 125$

b. $7 + 8 = x/3$
 $(7 + 8)3 = (x/3)3$
 $45 = x$

c. $4 \times 3^2 = x \times 8$
 $(4 \times 9)/8 = (x \times 8)/8$
 $4.5 = x$

d. $-15/3 = x + 1$
 $-5 - 1 = x$
 $-6 = x$

e. $x^2 = 27 + 35$
 $x^2 = 62$
 $\sqrt{x^2} = \sqrt{62}$
 $x = 7.9$

f. $x = \sqrt{79}$

$$x = 8.9$$

g. $x + 3 = \sqrt{38}$
 $x = 6.2 - 3$
 $x = 3.2$

h. $7 \times 5 = -40 + x$
 $35 + 40 = -40 + x + 40$
 $75 = x$

i. $3^3 = x/2$
 $(3 \times 3 \times 3)2 = (x/2)2$
 $54 = x$

j. $15 - 28 = x \times 2$
 $-13/2 = (x \times 2)/2$
 $-6.5 = x$

9. Two schoolchildren race across a playground for a ball. Tim starts running at a distance of 15 meters from the ball, and Jan starts running at a distance of 12 meters from the ball. If Tim's average speed is 4.2 m/s and Jan's average speed is 4.0 m/s, which child will reach the ball first? Show how you arrived at your answer. (See Sample Problem 1.) (Answer: Jan reaches the ball first.)

Time = Distance/Speed

$$t_{\text{Tim}} = 15 \text{ m}/4.2 \text{ m/s} \qquad t_{\text{Jan}} = 12 \text{ m}/4.0 \text{ m/s}$$

$$t_{\text{Tim}} = 3.6 \text{ s} \qquad t_{\text{Jan}} = 3.0 \text{ s}$$

$$3.6 \text{ s} > 3.0 \text{ s}$$

Hence, Jan reaches the ball first.

10. A 0.5-kg ball is kicked with a force of 40 N. What is the resulting acceleration of the ball? (See Sample Problem 2.) (Answer: 80 m/s²)

$$1 \text{ Newton} = 1 \text{ kg m/s}^2$$

Force = Mass \times Acceleration

$$F = ma$$

$$a = F/m$$

$$a = (40 \text{ kg m/s}^2)/0.5 \text{ kg}$$

$$a = 80 \text{ m/s}^2$$

Solutions to Selected Additional Problems

3. Sarah goes to the grocery store and spends half of her money. On the way home, she stops for an ice cream cone that costs \$0.78. Then, she stops and spends a one-fourth of her remaining money to settle a \$5.50 bill at the dry cleaners. How much money did Sarah have originally? (*Answer: \$45.56*)

$$(x/2 - \$0.78)/4 = \$5.50$$

$$x = \$45.56$$

4. Wendell invests \$10,000 in a stock portfolio made up of Petroleum Special at \$30 per share, Newshoe at \$12 per share, and Beans & Sprouts at \$2.50 per share. He places 60% of the money in P.S., 30% in N, and 10% in B & S. With market values changing (P.S. down \$3.12, N up 80%, and B & S up \$0.20), what is his portfolio worth six months later? (*Answer: \$11,856*)

Original investment: \$6,000 for 200 shares of P.S
\$3,000 for 250 shares of N
\$1,000 for 400 shares of B & S

6 months later:

$$\begin{aligned} \text{Portfolio value} &= (200) (\$30.00 - \$3.12) + (250) [\$12.00 + (0.8) (\$12.00)] \\ &+ (400) (\$2.50 + \$0.20) = \$11,856 \end{aligned}$$

5. The hypotenuse of right triangle ABC (shown in the text) is 4 cm long. What are the lengths of the other two sides? (*Answer: $A = 2 \text{ cm}$; $B = 3.5 \text{ cm}$*)

$$A = (4 \text{ cm}) (\sin 30^\circ) = 2 \text{ cm}$$

$$B = (4 \text{ cm}) (\cos 30^\circ) = 3.5 \text{ cm}$$

6. In triangle DEF , side E is 4 cm long and side F is 7 cm long. If the angle between sides E and

F is 50° , how long is side D ? (Answer: 5.4 cm)

$$D^2 = E^2 + F^2 - 2BC \cos 50^\circ$$

$$D^2 = (4 \text{ cm})^2 + (7 \text{ cm})^2 - (2) (4 \text{ cm}) (7 \text{ cm}) \cos 50^\circ$$

$$D = 5.4 \text{ cm}$$

7. An orienteer runs 300 m north and then 400 m to the southeast (at a 45° angle to north). If he has run at a constant speed, how far away is he from the starting position? (Answer: 283.4 m)

$$d^2 = (300 \text{ m})^2 + (400 \text{ m})^2 - (2) (300 \text{ m}) (400 \text{ m}) \cos 45^\circ$$

$$d = 283.4 \text{ m}$$

8. John is out for his daily noontime run. He runs 2 km west, then 2 km south, and then runs on a path that takes him directly back to the place he started at. a) How far did John run? b) If he has run at an average speed of 4 m/s, how long did the entire run take?

(Answers: a. 6.83 km; b. 28.5 min)

- a. Find the length of the hypotenuse of the triangle formed by the path that took John back to the starting place. The sum of all three sides of the triangle is the distance he ran.

$$h^2 = (2 \text{ km})^2 + (2 \text{ km})^2$$

$$h = 2.83 \text{ km}$$

$$d = 2.83 \text{ km} + 2 \text{ km} + 2 \text{ km} = 6.83 \text{ km}$$

- b. $t = 6,830 \text{ m} / 4 \text{ m/s}$

$$t = 1707.5 \text{ s} = 28.5 \text{ min}$$

9. John and Al are in a 15 km race. John averages 4.4 m/s during the first half of the race and then runs at a speed of 4.2 m/s until the last 200 m, which he covers at 4.5 m/s. At what average speed must Al run to beat John? (Answer: just over 4.3 m/s)

Total time for John to complete the race:

$$t = (7,500 \text{ m} / 4.4 \text{ m/s}) + (7,300 \text{ m} / 4.2 \text{ m/s}) + (200 \text{ m} / 4.5 \text{ m/s}) = 3487 \text{ s}$$

John's average speed:

$$s = l/t = 15,000 \text{ m}/3487 \text{ s}$$

$$s = 4.3 \text{ m/s}$$

Hence, Al must run at an average speed greater than 4.3 m/s to beat John.

10. A sailboat heads north at 3 m/s for 1 hour and then tacks back to the southeast (at 45° to north) at 2 m/s for 45 minutes. a) How far has the boat sailed? b) How far is it from its starting location? (*Answers: a. 16.2 km; b. 8.0 km*)

a. $l = (3 \text{ m/s})(3600 \text{ s}) + (2 \text{ m/s})(2700 \text{ s})$

$$l = 10.8 \text{ km} + 5.4 \text{ km}$$

$$l = 16.2 \text{ km}$$

b. $d^2 = (10.8 \text{ km})^2 + (5.4 \text{ km})^2 - (2)(10.8 \text{ km})(5.4 \text{ km})\cos 45^\circ$

$$d = 8.0 \text{ km}$$