

CHAPTER 1: WHAT IS BIOMECHANICS?

CHAPTER OVERVIEW

The study of human movement, kinesiology, encompasses multiple subdisciplines. Biomechanics is the subdiscipline in which biological systems are studied from a mechanical perspective. Mechanics is often 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 1 gives an overview of the relevant questions being answered by today's biomechanist. A basic understanding of mechanical concepts is essential for the practitioner as well as the researcher. Successful physical educators, athletic trainers, physical and occupational therapists, coaches, personal trainers, and physicians apply biomechanical principles daily.

Analysis of human movement may be either quantitative or qualitative and both are important to the practitioner. The chapter presents 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 the available services. Use cooperative practice during problem solving exercises. 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 TECHNIQUE

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 or not to stay. 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.)

YouTube

The internet provides a massive source of content which 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 for outside viewing or 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”.

Here are two concepts presented in Chapter 1.

Biomechanics

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

Metric System

http://www.youtube.com/watch?v=DQPO_q59xyw&feature=related

The links are provided as examples of videos which 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 others 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 select 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. Several use very low-cost equipment, but are still effective for helping students learn the concepts. Here is an example of a site that has some low-cost experiments, many relevant to the biomechanics concepts presented in the text. It also provides links to other lab sites.

<http://www.physicsclassroom.com/lab/>

Here is an example of one vendor for low-cost lab equipment.

<http://www.arborsci.com/>

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.)

$$\text{time} = \text{distance}/\text{speed}$$

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

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

3.6s > 3.0s so Jan reaches the ball first.

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

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

$$\text{Force} = \text{mass} \times \text{acceleration} \quad F = ma$$

$$a = F/m$$

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

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

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 quarter of the remaining money on a \$5.50 bill at the dry cleaners. How much money did Sarah have originally? (\$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 \$.20), what is his portfolio worth 6 months later? (*\$11,856*)

original investment: \$6,000 buys 200 shares of PS
 \$3,000 buys 250 shares of N
 \$1,000 buys 400 shares of B&S

6 months later:

$$\text{portfolio value} = (200)(\$30.00 - \$3.12) + (250)(\$12.00 + (0.8)(\$12.00)) \\ + (400)(\$2.50 + \$0.20) = \$11,856$$

5. The hypotenuse of right triangle ABC (shown in text) is 4 cm long. What are the lengths of the other two sides? (*A = 2 cm, B = 3.5 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? (*5.4 cm*)

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

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

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

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? (*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. 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? (a. 6.83 km, b. 28.5 minutes)

a) Find the length of the hypotenuse of the triangle formed by the path that took him back to the starting place. The sum of all three sides of the triangle is the distance run.

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

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

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

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 in order to beat John? (*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:

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

$$s = 4.3 \text{ m/s} \quad \text{Al must run at an average speed greater than 4.3 m/s to beat John.}$$

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 at this point from its starting location? (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) $d^2 = (10.8 \text{ km})^2 + (5.4 \text{ km})^2 - (2)(10.8 \text{ km})(5.4 \text{ km})\cos 45^\circ$

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

CHAPTER 2: KINEMATIC CONCEPTS FOR ANALYZING HUMAN MOTION

CHAPTER OVERVIEW

Communicating specific information about human movement requires specialized terminology that identifies body positions and directions. The anatomical reference position is used as the starting place. The sagittal, frontal, and transverse planes, with their respectively associated mediolateral, anteroposterior, and longitudinal axes provide major frames of reference for the description of body movements. The three general categories of movement are linear motion along a straight or curved line, rotary motion around an axis, and general motion, which is a combination of linear and rotary motion. A body of terminology is presented that describes direction with respect to the human body and the actions that occur at joints. The Cartesian coordinate system is presented as a spatial reference system.

Physical educators, clinicians, and coaches all routinely perform qualitative analyses to assess, correct, or improve human movement. Visual observation is the most commonly used approach for qualitatively analyzing mechanics. To be effective, the analyst must have knowledge of the biomechanics of the movement and must carefully plan and conduct the analysis. This chapter introduces a systematic approach for planning and conducting qualitative analysis and also introduces various tools used for such investigations.

TEACHING TIPS

Physical practice of the various movements will help students learn and remember the terminology. Use movement examples from a variety of activities including those specific to the represented students and those common to all movers. A dancer can demonstrate a pirouette (transverse plane movement around the longitudinal axis), a gymnast can demonstrate a cartwheel (frontal plane movement around the anteroposterior axis), and a student in a wheel chair can demonstrate the action at the elbow during forward propulsion (sagittal plane movement around the mediolateral axis). Begin the practice of qualitative analysis by having students observe (either live demonstration or video demonstration) the more obvious mechanical problems in a movement. Practice analysis throughout the semester to increase familiarity with the techniques.

ASSESSMENT TECHNIQUE

Background Knowledge Probe: Students are asked to answer a few questions about a topic *before* the topic is presented in class. This “pre-test” information can be used to determine whether students have the required background to proceed with certain information. For example, it is helpful to know what background students have in anatomy before proceeding with biomechanics. The information may be used to determine a starting point for the class *or* to determine who needs to be referred for remedial work. (Angelo, T.A. & Cross, P.K. (1993). *Classroom Assessment Techniques* (2nd ed.). San Francisco: Jossey-Bass.)

YouTube

Here are two concepts presented in Chapter 2.

Planes of Motion

<http://www.youtube.com/watch?v=fDjCkWKfwj0>

Anatomical Directions

<http://www.youtube.com/watch?v=CHKFFgxxw1M&feature=related>

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