Model of Prosthetic Leg

Grade Level:	Total Time Required:
5	Six 30 minute class sessions Two 30 minute class sessions (optional)

Prepared By: Bryan Hubbard, John Grutzner, Kari Clase, Alyssa Panitch, Nancy Tyrie, and Jonathon Bernhard

Lesson Objectives:

In this lesson, students will design and build a small model of a prosthetic leg that will be capable of kicking a ball.

Students will be able to:

1. Explain the joint structure and how the leg moves in a kicking motion.
2. Design and build a prototype of a prosthetic leg.
3. Measure weight, mass, volume, and density of materials.
4. Explain the difference between mass, volume, and density.
5. Through the design process, develop the best design for the task of kicking a ball.

Indiana Standards:

5.PS.1 Describe and measure the volume and mass of a sample of a given material

5.PS.4 Describe the difference between weight being dependent on gravity and mass comprised of the amount of matter in a given substance or material.

3-5.E.1 Identify a simple problem with the design of an object that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost.

Next Generation Science Standards: Discipline Core Ideas 3-5.ETS1-1 Identify a simple problem with the design of an object that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost. Science/Engineering Practices 1. Asking questions (for science) and defining problems (for engineering) 6. Constructing explanations (for science) and designing solutions (for engineering) 7. Engaging in argument from evidence Crosscutting Concepts 2. Cause and effect: Mechanism and explanation. 3. Scale, proportion, and quantity.
Common Core Mathematics:
Common Core English and Language Arts:

Concepts and Vocabulary

Term	***Defined by a scientist or engineer***	***Defined by a student***
Weight	Force with which a body is attracted toward the earth or celestial body, equal to the product of the mass and local gravitational acceleration.	The property used to explain how heavy something is.
Mass	Measures the amount of material it contains and causes it to have weight in a gravitational field. It measures the resistance to acceleration.	Property that describes the “stuff” that makes up an object.
Volume	The amount of space occupied by a three-dimensional object as measured in cubic units (e.g., quarts or liters).	The amount of space that matter takes up.
Density	Mass per unit volume.	The quantity of something per unit measure.
Prosthetic	Artificial device to replace or augment a missing or impaired part of the body.	Artificial device used to replace a missing body part, such as arm or a leg.
Lever	A rigid piece that transmits and modifies force or motion when forces are applied at two points and it turns about a third; specifically, a rigid bar used to exert a pressure or sustain a weight at one point of its length by the application of a force at a second and turning at a third on a fulcrum.	A rigid bar pivoted about a fulcrum
Hinge Joint	A joint between bones (as at the elbow) that permits motion in only one plane.	A joint allowing movement in one plane only.
Ball and Socket Joint	A joint in which a ball moves within a socket so as to allow rotary motion in every direction within certain limits; an articulation (as the hip joint) in which the rounded head of one bone fits into a cuplike cavity of the other and admits movement in any direction.	A joint that can rotate within a socket; a freely moving joint in which a sphere on the head of one bone fits into a rounded cavity in the other bone
Gliding Joint	A diarthrosis in which the articular surfaces glide upon each other without axial motion – also called arthrodia, plane joint.	A freely moving joint in which the articulations allow only gliding motions (for example, wrist, and ankle).

Equipment, Materials, and Tools

Materials		
Plastic golf ball (no holes)	Brass fasteners	Salt (extension activity)
Golf ball	Dry wall corner bead (cut into short pieces approximately 6 inches)	Small cable ties or zip ties
Rubber bands (multiple sizes)	Masking tape	Short pieces of wire

Tools		
Heavy duty scissors or sheet metal cutters (cut beading)	250 ml graduated cylinder, measuring cup, or beaker	Soccer ball and bowling ball for demonstration
Scale or balance (in grams)	Tape Measure	

Examples of dry wall corner bead:
http://www.homedepot.com/p/10-ft-Vinyl-Corner-Bead-V114CB10/202093365

http://www.homedepot.com/p/Clark-Dietrich-10-ft-PVC-L-Mould-Corner-Bead-12VINL10H/202848954

Special Materials Notes and Comments

Common Student Challenges or Misconceptions Related to the Topic:
- Differentiating between weight, mass, and volume.
- Applying the concept of density.

Note:
The drywall beading is readily available and very inexpensive. It provides many options for rubber band placement and joint location. It is available at most home improvement stores (Lowe's, Home Depot, Menard's, etc.). The cost for leg pieces for one class of 20 would be approx. $3.00.

Synopsis of Engineering Design Activity

Synopsis of the Design Activity:

Problem:	Boiler BioTech, a company in Warsaw, Indiana, needs assistance in designing a leg for a young child. The prosthetic leg will need to be designed so that it will be able to kick a soccer ball.
Goal:	Design a prosthetic leg for a young child so they may kick a soccer ball.
Who is the client:	Boiler BioTech
End-User:	Young child
What is the design:	Design a prosthetic leg for a young child.
Criteria:	• The leg should hinge like a real joint (move back and forth). • The leg is being designed to strike a ball (move the ball or propel it on its own).
Constraints:	• A list of items and potential monetary value is provided. You may set a maximum amount that students may spend. • Only available materials may be used. • Time allowed for construction.

Lesson Plan #1

Guiding Question - What are important attributes of a prosthetic leg?

Time: 30 minutes

Procedure:

Introduce the challenge:

"You will work in teams to design a small model of a prosthetic (artificial) leg to kick a ball. The effectiveness of your design will be based on the distance that you can kick each of the balls (plastic golf ball, and regular golf ball)."

Initial Design Brainstorming:

Discuss a scenario where someone needs an artificial leg and would like to be able to kick a ball with the prosthetic device.

1. Outside activity – Have the students kick a soccer ball outside to help them better understand how a leg works to kick a soccer ball.

2. Show modern day prosthetic leg devices.

Image retrieved December 2011 from http://freedomoandp.com/images/kneetypes.jpg.

3. Discuss the important attributes for a prosthetic leg and record these in a design notebook. (e.g., weight, ability to move, reliability).

4. Discuss types of joints in the human body (e.g., hinge, ball and socket, gliding joints). Which type of joint could you use for the leg? (pictures on next page)

Types of Joints

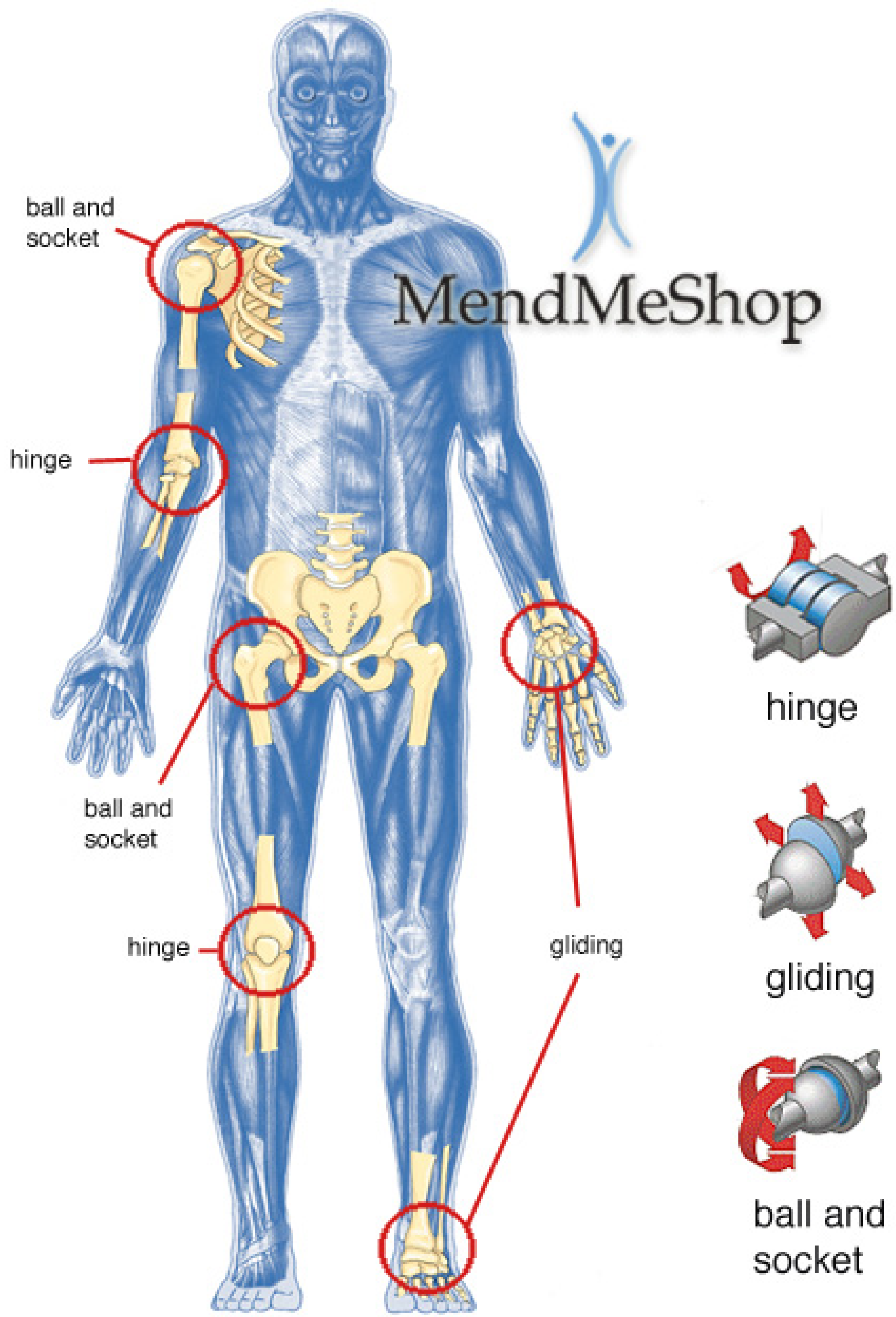


Image retrieved December 2011 from
http://www.musclesmagic.com/wp-content/uploads/2009/07/400px-Muscles_anterior_labeled.png.

Lesson Plan #2

Guiding Question – Can you build a model of a prosthetic leg?

Time: 60 minutes

Procedure:

Initial Design Brainstorming:

1. Introduce components or materials that the students can use to build the prosthetic leg (e.g., corner bead pieces, rubber bands, brass fasteners, zip ties, etc.).

2. Instruct the students to sketch individual designs for the leg in their design notebooks.

   Ask: What are the important features?

3. Have the group decide on one plan after they share their designs. The design could be a specific design of one student or a combination of designs.

4. Make sure the students understand how all the components work. For example, if using zip ties, they only get one chance to make them work.

5. Students will construct one prototype per team.

6. Have the students test their designs by kicking the balls on carpet (i.e., kicking on a hard floor will cause the regular golf ball to roll toward the low spot in the room).

7. Have each team measure the distance their balls were kicked and record in their design notebook.

8. Share team data by putting information on the class whiteboard or chalkboard.

Discussions of redesign:

1. Have the students discuss how they would improve their design and note it in their design notebook.

Design Criteria:

1. The leg should hinge like a real joint (i.e., move back and forth).

2. The leg is being designed to strike a ball (i.e., move the ball or propel it on its own). Typically, the rubber bands would be used to make the spring loaded leg snap to propel the ball.

3. A list of items and potential monetary value is provided. Students may be asked to determine how much their design costs and they can “buy” additional items, if needed.

4. Elapsed time can be recorded for further math exercises.

5. The lesson is meant to design something that functions like a leg when it kicks a soccer ball. Students do not have to mimic anatomy.

Possible cost for items to link with a classroom economy

Leg (Plastic Piece)	$10
Brass Fastener	$5
Rubber Band	$2
Zip Tie	$1
Wire	$0.50
Packet	$35

Examples of Possible Leg Constructions

Example 1

Example 2

Lesson Plan #3

Guiding Question - How would you determine the volume of a ball?

Time: 60 minutes

Procedure:

Volume, mass, and density of balls to be kicked:

1. Have a class discussion:

   Ask: Will your prosthetic leg be able to kick a real soccer ball?

2. Discuss the concept of scaling and have students record their answers in their design notebook.
   - Show a real soccer ball compared next to a child's leg and compare to a golf ball next to their design.
   - Show a hollow golf ball next to a real golf ball.

   Ask: Which one is most like a soccer ball (e.g., hollow golf ball or real golf ball)?
   Which ball will go the farthest when it is kicked?

3. Discuss the weight of the balls and the size of the balls and have students record their answers in their design notebook.

   Ask: Which one is heaviest?
   Which one is the biggest?
   How would you find the answers to these questions?

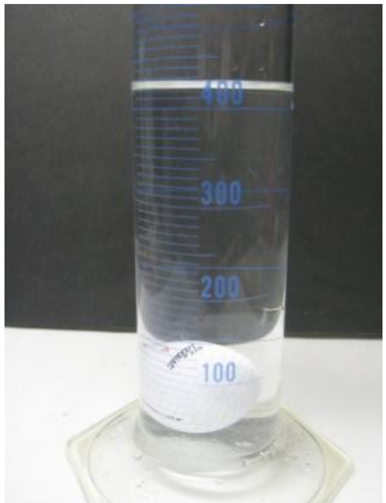
4. Introduce new vocabulary: Weight, Mass, Volume, Density.

5. Formal teacher presentation on using displaced volume to determine the volume (i.e., size) of an object.

6. Measurement of Volume:
   - Provide students with a graduated cylinder or measuring cup of water and both golf balls
   - For the golf ball, have the students record the level of the water in the beaker
   - Discuss what would happen if they put a ball into the water (i.e., the water rises based on the volume of the ball).
   - Have the students record the water level before and after the regular golf ball is placed into the beaker in their design note books. The difference is the volume of the object.
   - What is the volume? Record in design notebook

- What happens when the plastic golf ball is placed in the water (i.e., it floats)? Assume the two golf balls are equivalent and use the regular golf ball for both volumes.
- Extra Question: What fraction of the plastic ball is below the surface – why?

No Golf Ball



Golf Ball

No Golf Ball

Golf Ball

Note: The difference should be approximately 40 milliliters which is equal to 40 cm^3.

Lesson Plan #4

Guiding Question - Which ball will go the farthest when kicked?

Time: 30 minutes

Procedure:

1. Measurement of Mass.
    - Place each ball on the scale and determine the mass in grams. Record in design notebook.
    - Discuss the similarity in volumes of the ball but the disparity in masses.
    - Why are the masses different? Introduce the concept of density.
    - Calculate density (mass/volume) using the mass and volume determined.
      Note: 1 milliliter = 1 cm^3

2. Have the students answer the question:
    - Which ball will go the furthest when kicked on the carpet? *(i.e., the ball with less mass)*

Additional Information on Densities

<u>Standard Golf Ball:</u>
Mass = 46 grams
Diameter = 4.3 cm
Volume = $\frac{4}{3}\pi r^3$ = 41.6 cm^3 *(Note: 1 cm^3 = 1 ml)*
Density = $\frac{Mass}{Volume}$ = 1.1 g/cm^3

<u>Plastic Golf Ball:</u>
Mass = 3.5 grams
Diameter = 4.3 cm
Volume = $\frac{4}{3}\pi r^3$ = 41.6 cm^3
Density = $\frac{Mass}{Volume}$ = 0.085 g/cm^3

Analogy between a Bowling Ball and a Soccer Ball

A simple analogy between a soccer ball and a bowling ball

- The soccer ball has about the same density as the plastic golf ball
- A 12 pound bowling ball has about the same density as a golf ball

Which one do you think you could kick farther?

Discuss importance of doing a test at a smaller scale while maintaining the key attributes such as density.

Additional Information:

<u>A Standard 12 lb Bowling Ball</u>
Mass = 5443 g
Diameter = 22 cm
Volume = 5575 cm^3
Density = 0.98 g/cm^3

<u>A Size 4 Soccer Ball (typical for 8 to 12 year olds):</u>
Mass = 370 g
Diameter = 20 cm
Volume = 4,288 cm^3
Density = 0.086 g/cm^3

Lesson Plan #5 (Optional)

Guiding Question - What makes the regular golf ball more dense (have a higher density)?

Time: 30 minutes

Procedure: Teacher Demonstration

Show a change in density while maintaining the same volume.

1. Poke a hole in one of the hollow plastic golf balls.
2. Fill with salt using a dosing syringe.
3. Weigh the golf ball and note in design notebook.
4. Use the same volume of the golf ball determined in the first test.
5. What is the density of the new ball?
   - Mass / Volume
   - Density similar to a golf ball

6. Have a class discussion on how the density changed.
   - You can change the density by adding mass without changing the volume.
   - Discuss the mass of air versus the mass of a solid (e.g., sand).

Additional Information on Densities

Sand-filled Golf Ball:
Mass = 47.6 grams
Diameter = 4.3 cm
Volume = $\frac{4}{3}\pi r^3$ = 41.6 cm^3 *(Note: 1 cm^3 = 1 ml)*
Density = $\frac{Mass}{Volume}$ = 1.1 g/cm^3

Lesson Plan #6 (Optional)

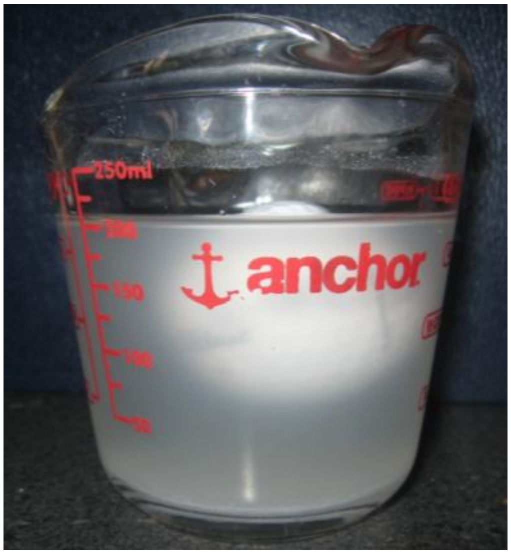
Guiding Question - How can you make the golf ball float?

Time: 30 minutes

Procedure: Teacher Demonstration

Show that you can make a regular golf ball float by using a liquid with a higher density than water.

1. Fill a small container with water.
2. Record the volume before and after the addition of salt.
3. Stir in salt to increase the density (i.e., 25 grams per 100 ml of water will make the ball float). Demonstrate that the golf ball can float in the solution.



Floating Golf Ball in Salt Water Solution

Principles learned:

- You can change the density by adding mass without changing the volume (i.e., same as changing the density of the ball).
- Increasing the density of the liquid beyond the density of the ball will cause the ball to float.
- Density is the ratio of mass to volume.

Assessment

The following are possible sources of formative and summative assessment:

Formative

- Design notebooks (individual) – Note how students identify and clearly label their drawings; Identify the types of science vocabulary students use in their notebooks (i.e., tally the number of times each concept is used). Note how students record data from testing their prototypes and how well they explain their results (i.e., patterns in the data).
- Presentation of design to class by the team. Provide positive design attributes, how design criteria were met, and possible redesigns.

Summative

- Participation (group) – Note level of engagement; questions students asked; how well they worked in a group; how well each team met the goals of the task
- Other (individual and/or group) – Create a short pre- and post-test that highlights key science vocabulary terms; Present a new situation or new problem on the same theme

Lesson Extensions and Resources

Activity Extensions:

Students could write persuasive letters to their respective design clients.
Students could share their designs to a younger audience and ask for their feedback.

Web Resources:

http://www.tryengineering.org/lesson_detail.php?lesson=4

http://solar-center.stanford.edu/teachers/

http://www.sciencebuddies.org/science-fair-projects/project_ideas/Chem_p088.shtml

Design Activity

A young child, who has a prosthetic leg, really enjoys playing sports. Unfortunately, their current prosthesis does not allow them to play soccer. Boiler BioTech, a company in Warsaw, Indiana, needs you to design a prototype of a prosthetic leg to kick a soccer ball. The leg does not need to mimic human anatomy.

Design Criteria:

- The leg should hinge like a real joint (i.e., move back and forth)

Design Constraints:

- May only use the materials provided
- Time

.

Design Notebook

Individual Design

Team Design