When a student builds an electric guitar in this program, they are getting a hands-on introduction to a minimum of two wood species. This activity will give students an opportunity to learn about the woods that compose their instrument. Characteristics that will be explored include:

- Native Region
- Scarcity/Sustainability
- Relative Hardness
- Density
- Common Uses
- Color, Grain and Figuring
- Cost

Students will learn about CITES regulation, the Janka hardness scale, board-foot calculations for both quantity and cost, density calculations and lumber grading for both quality and surfacing.

Learning Objectives:

1. Identify a wood species based on color, grain and figuring
2. Use the Janka scale to arrange a selection of woods in order of increasing hardness
3. Calculate the quantity, in board-feet, of a sample of lumber
4. Calculate the density of lumber, in pounds-per-board-foot, for a sample of lumber
5. Calculate the cost for an order of lumber, based on cost-per-board-foot
6. Know the implications of CITES regulations on the trade of lumber across the globe
7. Recognize notation for surfacing when placing a lumber order

Standards:

CCSS.Math.Content.HSN.Q.A.1 - Use units as a way to understand problems and to guide the solution of multi-step problems

CCSS.Math.Content.HSN.Q.A.3 - Choose a level of accuracy appropriate to limitations on measurement applications

HS-PS2-6 Molecular-Level Structure of Designed Materials

Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Materials Required:

1. A computer with internet access for each student
2. Colored pencils
3. The document, "STEM Guitar Building - Wood Species Assignment," located here:

https://docs.google.com/document/d/1NKHrj07gpNgtmctbYfEcBwx1x-5xGPj9LzfB1BFwCEs/edit?usp=sharing

4. A wood identification veneer kit - suggested: amazon.com ASIN B003F0C9EW
5. Pencil and calculator for density, board-foot and cost calculations
6. An assortment of wood samples of varying size (from scraps/cutoffs to full boards)
7. Calipers to accurately measure the thickness of various wood samples
8. Tape measure to accurately measure the width and length of various wood samples
9. A bathroom or luggage scale to accurately weigh various wood samples
10. Guitar kits (prior to finish and assembly!)
11. A price list for a local hardwood supplier to be used for cost calculations

Safety:

1. Watch for splinters and be sure to wear eye protection in a lab setting.

References:

1. The Wood Database - Wood Finder: http://www.wood-database.com/wood-finder
2. CITES Regulation: https://www.cites.org/eng/disc/what.php
3. Lumber Grading and Notation - American Hardwood Export Council:
   https://www.esf.edu/wus/documents/IllustratedGradingGuide.pdf
4. Lumber Surfacing and Notation - The Wood Whisperer:
   https://www.thewoodwhisperer.com/articles/s2s-and-s4s-what-gives

Activity:

When your students build an electric guitar in this program, they will be getting a hands-on introduction to a variety of wood species. The neck and fingerboard alone will likely be of two different species, and the body could be comprised of one or more species. This two-part activity will provide an opportunity for each of your students to learn about the woods that compose their instrument, followed by a group exploration of the various characteristics that play a role in identifying, grading, measuring and purchasing lumber.

Directions for Students - Part One: Identifying Your Lumber

1. Your teacher will provide a wood identification kit, which is a pack of labeled veneers. Choose a wood from your guitar kit (body, neck or fingerboard) that catches your interest, and match it to a veneer from the identification kit. Double check with a classmate, then your teacher, before writing down the name and committing to that species of wood for the remainder of this first part of the activity.

2. Your teacher will share an electronic document with you to complete for the species of wood you selected. *Your task is to research the various characteristics of your chosen wood species and complete the document, then print it out for use in class.* Your teacher has been provided with a list of online resources that can be used to locate the necessary information. They may share these resources with you, or they may leave it up to you to locate the information on your own.

3. After printing your completed document for the wood species you selected, use a colored pencil to shade in the region(s) of the globe where your species is found.

Directions for Teachers - Part Two: Lumber Characteristics

Ask students to share/present their completed documents for the wood species they selected. A wall space or bulletin board can be used to display the documents, and the corresponding veneer from the wood identification kit can be affixed to the bottom of each document. These documents can be referred to in the following discussions, demonstrations and calculations:

1. Janka Hardness Scale - Have students list the wood species from the posted documents in order of increasing Janka Hardness Scale. Share the definition of Janka hardness scale (The **Janka scale** is used to determine the relative **hardness** of particular domestic or exotic wood species. The **Janka** test measures the amount of force required to embed a 0.444" steel ball into the wood to half of its diameter. - bellforestproducts.com) and ask why Janka rating is so important for the selection of woods that would be appropriate for flooring applications. Suggested video to supplement the discussion: https://www.youtube.com/watch?v=9lodheHJCDM

2. Scarcity/Sustainability (CITES Status) - Challenge students to define "CITES" (The Convention on International Trade in Endangered Species of wild Fauna and Flora) and note that none of the wood species on the completed documents are impacted (not currently, anyway!) by CITES regulation. Rosewood, on the other hand, has recently been upgraded in CITES status (2017). Suggested resource to supplement the discussion around CITES and rosewood: https://www.taylorguitars.com/cites

3. Density Calculations - Choose a wood species from the completed documents and write its density (average dried weight - pounds per cubic foot) on the chalk/white board. Challenge students to calculate the weight of a board of that species having dimensions of 4.5 inches wide x 6 feet long x 1.75 inches thick:

   Weight = Volume * Density = (4.5/12 * 1.75/12 * 6) * Density = _____ pounds

   Note: *Units matter!* Since density is provided in pounds per cubic foot, the three dimensions that are used to determine volume (length, width, thickness) must be in units of feet. This explains the instances of division by 12 for the width and thickness dimensions!
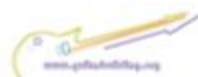
Follow-Up: Challenge students to calculate the density, in pounds per cubic foot, of a sample of wood. Supply calipers for accurate measurements of thickness, and a tape measure for accurate measurements of width and length. Have students use a luggage or bathroom scale to weigh their wood sample, then perform the necessary calculation to determine density. If you know the species of wood, challenge your students to look up the average dried weight of that species of wood and compare it to their calculations.

Example: Calipers indicate a thickness of 0.754 inches, and a tape measure indicates a width of 4-½ inches and a length of 4 feet 3-⅛ inches. Convert dimensions to inches, as decimals: 4.5 inches wide and 51.125 inches long. Calculate volume, in cubic feet: 0.754/12 * 4.5/12 * 51.125/12 = 0.100 cubic feet

Since *Weight = Volume * Density*, we can determine that *Density = Weight / Volume*

If the wood sample weights 4.84 pounds, then the density of the sample is:

4.84 / 0.100 = *48.4 pounds per cubic foot*

4. <u>Board-Foot Calculations</u> - Ask a student for the piece of wood that they used for the density calculation and hold it up to show the class. Ask the student for the dimensions of the sample and write the dimensions on the chalk/white board for all to see. Explain that lumber is commonly priced and sold in units of board-feet, which is very similar to the volume calculations that were just performed. To calculate lumber quantity in board feet, the thickness of the board is expressed in inches, while the width and length are expressed in feet. Demonstrate the calculation on the board, then challenge students to do the same for their sample.

Example: Using the previous example of .754 inches thick x 4-½ inches wide by 4 feet 3-⅛" long: Lumber Quantity = 0.754 * 4.5/12 * 51.125/12 = *1.205 board-feet*

Follow-Up: At lumber dealers, the thickness of a board is commonly measured in "quarters." For example, 6/4 would be read as "six-quarter" lumber, and is equivalent to 1.5 inches for the purpose of inventory and sales. For the above example, although the thickness was 0.754 inches, it would likely be listed as 4/4 at a lumber dealer. The board-foot calculation used to price the board would then be:

4/4 * 4.5/12 * 52/12 = 1.625 board-feet

Typically, lumber dealers will only work in "even" quarter increments for their boards: 4/4, 6/4, 8/4, 10/4, 12/4, etc. Challenge your students to re-work their board-foot calculations for their sample using the "quarter" dimension for the thickness of their sample.

5. <u>Cost Calculation</u> - Lumber is sold by the board-foot. Tell each student to pretend that their sample of wood is actually the species that they chose for the document assignment. Have them determine the would-be cost of their sample of wood, based on the *common local cost* from their completed document.

   Example: The above example had a calculated volume of 1.625 board feet. At a local hardwood supplier, 4/4 S2S Honduran Mahogany sells for $8.20 per board-foot. The cost of this particular board, if Honduran Mahogany, would be:

$$1.625 * 8.20 = \$13.33$$

   Follow-Up: Draw your students' attention to the "S2S" that was used in the above example, and explain to them that "S2S" means "surfaced 2 sides." This means that the front and back faces of the board have been planed, and possibly even sanded, flat. The edges have been left rough. Challenge your students to take a best guess at the meaning of the following typical notations used in lumber sales:

   S4S - Surfaced Four Sides - Front and Back, and both lengthwise edges
   S3S - Surfaced Three Sides - Front and Back, and one lengthwise edge
   RGH - Rough cut - No surfacing.

   Optional: If the wood samples used for this activity are of varying surface grades, then ask students to return their wood samples to the front of the room in stacks labeled "S2S", "S3S", "S4S" and "RGH"

   Close the Activity with the "*Know Your Lumber*" Assessment.

Assessment
Know Your Lumber

1. Which of the following statements is accurate for a Janka Hardness index of 2,215?

    A. A force of 2,215 pounds is required to drive a steel ball with a diameter of 0.444" into a sample of wood to a depth of 0.222"
    B. A force of 2,215 Newtons is required to drive a steel ball with a diameter of 0.444" into a sample of wood to a depth of 0.222"
    C. A force of 2,215 pounds is required to drive a steel ball with a diameter of 0.444" into a sample of wood to a depth of 0.444"
    D. A force of 2,215 Newtons is required to drive a steel ball with a diameter of 0.444" into a sample of wood to a depth of 0.444"

2. The international trade of endangered species, both plants and animals, is regulated by a convention known as CITES.

    True   -or-   False

3. Since 2017, the following type of wood that is common to guitar building was made subject to stricter regulation under CITES.

    A. Basswood
    B. Ash
    C. Rosewood
    D. Maple

4. Calculate the density of a sample of wood that weighs 14 pounds, given that its dimensions are 2.25 inches thick, 8 inches wide and 6 feet long.

    A. 10.5 pounds per cubic foot
    B. 18.67 pounds per cubic foot
    C. 7.71 pounds per cubic foot
    D. 1.56 pounds per cubic foot

5. "S4S" is the common notation used in lumber sales to refer to a board that has been planed flat on both faces and both lengthwise edges, or, "surfaced four sides."

    True   -or-   False

6. Swamp ash has an average dried weight of approximately 30 pounds per cubic foot. A billet of swamp ash for an electric guitar body has dimensions of 1.75" thick, 13" wide and 20" long. Approximately how much will the billet weigh?

    A. 15.17 pounds
    B. 7.59 pounds
    C. 15.81 pounds
    D. 7.90 pounds

7. A 6/4 black walnut board from the Pacific Northwest measures 7.5" wide and 42" long. What is the volume of the board, in board-feet?

    A. 3.28 board feet
    B. 39.38 board feet
    C. 2.38 board feet
    D. 32.89 board feet

8. A S2S African Mahogany board that is 9" wide and 72" long sells for $68.51. If the per-board-foot cost is $10.15, then which of the following statements is true?

    A. The board is 6/4
    B. The board has a volume of 6.75 board-feet
    C. The board has been planed flat on both faces
    D. All of the Above

9. The following is an excerpt from a pricing sheet for a local hardwood supplier. Calculate the cost of a S2S-FAS Padauk board having the following measurements:

    1.80" thick x 6" wide x 42" long

Imported/Exotic (S2S - FAS)	4/4	6/4	8/4	12/4
Bubinga	16.83	18.20	22.00	-
Cocobolo	38.22	42.54	48.00	-
Mahogany (African)	8.95	10.15	12.00	13.30
Padauk	11.00	13.30	15.75	18.00

    A. $55.13
    B. $49.61
    C. $41.90
    D. $330.75
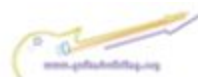
Assessment Key:

1. A - A force of 2,215 pounds is required to drive a steel ball with a diameter of 0.444" into a sample of wood to a depth of 0.222"
2. True
3. C - Rosewood
4. B - 18.67 pounds per cubic foot
5. True
6. D - 7.90 pounds
7. A - 3.28 board feet
8. D - All of the Above
9. A - $55.13

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