Properties of Wood

Society of Wood Science and Technology

Teaching Unit Number 2

Slide Set 2 - Activities

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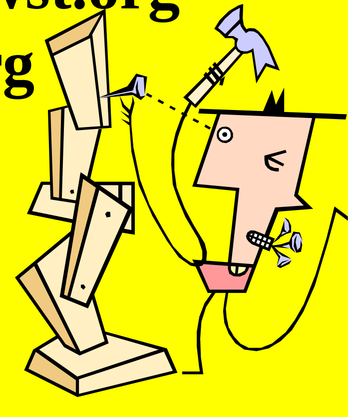


The activities in this slide set are designed to accompany the information presented in SWST's teaching units Structure of Wood (Unit 1, Slide Set 2) and Properties of Wood (Unit 2, Slide Set 1).

<u>You should complete both those units prior to conducting the activities described here.</u>

We hope you enjoy the **wonders of wood**!!

Supplies for these activities can be obtained from the following sources:

Aldrich – chemicals and laboratory equipment; Milwaukee, WI (800) 558-9160 www.sigma-aldrich.com

Fisher Scientific – chemicals and lab equipment; Pittsburgh, PA (800) 766-7000 www.fishersci.com

Carolina Biological Supply Company; Burlington, NC (800) 334-5551 www.carolina.com

Edmund Industrial Optics; Barrington, NJ (800) 363-1992 www.edmundoptics.com

Sigma – Biochemicals and Reagents; St. Louis, MO (800) 325-3010 www.sigma-aldrich.com

Cole-Parmer Instrument Company; Vernon Hills, IL (800) 323-4340 www.coleparmer.com

Daigger Discount Lab Supplies; Lincolnshire, IL (800) 621-7193 www.daigger.com

Micro-Mark – The Small Tool Specialists; Berkeley Heights, NJ (800) 225-1066 www.micromark.com

Grainger – everything from tools to light bulbs to soap; Charlestown, MA (888) 361-8649 www.grainger.com

Craftsman Power and Hand Tools; Manteno, IL (800) 290-1245 www.sears.com

Woodworker's Supply Inc; Casper, WY (800) 645-9292 www.woodworker.com

Rockler Woodworking and Hardware; Medina, MN (800) 233-9359 www.rocklerpro.com

Woodworkers Library – books, videos, and plans; Linden Publishing, Fresno, CA (800) 345-4447 www.lindenpub.com

Manny's Woodworkers Place – books and tools; Lexington, KY (800) 243-0713 www.mannyswoodworkersplace.com

Garrett Wade – woodworking tools; New York, NY (800) 221-2942 www.garrettwade.com

Woodcraft Supply Corp.; Parkersburg, WV (800) 225-1153 www.woodcraft.com

Activities

1. Chemical Extractives
2. Anatomy
3. Hygroscopicity
4. Anisotropy
5. Specific Gravity
6. Engineering

1. CHEMICAL EXTRACTIVES

The study of wood is, to a large degree, the study of organic chemistry, since wood is comprised of natural organic molecules. Three classes of organic molecules which are common to all woods are **cellulose, hemicelluloses, and lignin**. These three groups are called “structural polymers” because they comprise the basic framework of the wood.

Another diverse group of organic chemicals, which vary with the species of tree, are called **extractives**. Extractives are “nonstructural polymers” since they do not contribute to the structural framework. Extractives do, however, impart unique properties to wood. Redwood, for example, is naturally resistant to decay because the extractives in the wood are toxic to insects and fungi. Other interesting properties may result from the presence of extractives, as you will see in this exercise.

Supplies you will need:

- Small blocks (at least 1” square and 3” long) of black locust wood (*Robinia pseudoacacia*), honeylocust (*Gleditsia triacanthos*), pine (*Pinus* spp.), spruce (*Picea* spp.) and walnut (*Juglans nigra*). Any wood type will work in this activity, but only the black locust and honeylocust will fluoresce. You can get the more common ones at home improvement and lumber stores. But the black locust and honeylocust will probably have to come from specialty stores or woodworking catalogs such as Woodworkers Supply (800) 645-9292. Also, check the internet for other sources, such as www.woodworker.com, www.colonialhardwoods.com and www.woodweb.com
- file, rasp, or hand plane
- Chemical solvents

  acetone, water, ethanol (ethyl alcohol), and cyclohexane (hexahydrobenzene)
- Beakers
- Small vials or flat bottom-bottles
- Small funnel
- Taper-pointed paint brushes – 1 for each participant
- Notebook paper
- Long wave (~365 nanometers) ultraviolet light (“black” light) found at most hardware, home improvement, and discount stores.

Activity*:

•file or rasp a portion of each block into sawdust or plane off some shavings

•prepare a mixture of 90% acetone and 10% water; about 100 ml to start

•place the wood in a beaker and cover with enough acetone/water solvent to equal about twice the volume of the wood

•soak the sawdust or planer shavings from each block in the solvent for 6 hours or overnight (extraction can be improved by using a magnetic stir rod); do this for each wood type in a separate beaker

•prepare a mixture of 50% ethanol and 50% cyclohexane

•remove the acetone/water mixture and replace it with the 50/50 ethanol/cyclohexane; soak the blocks 6 hrs or overnight

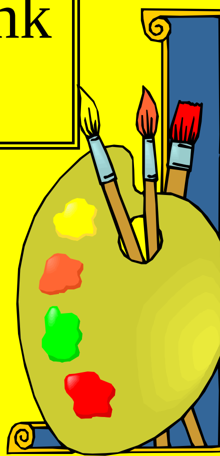
•label the vials with a wood type and pour off some of the extractive solution into the vials

*be sure to maintain adequate ventilation during this activity, you should perform the extraction in a fume hood if one is available

Activity continued:

- Now you should dip a paint brush into the solution in one of the vials and then paint your name on a piece of notebook paper. Allow it to dry so that your name becomes invisible. Now place your paper under long wave ultraviolet light. Do this for each wood type. What do you see?

- You also have the original wood blocks that were not extracted with the organic solvents. Darken the room and shine the black light on the wood blocks. Notice that some species are fluorescent and some are not. Why do you think that is? All is explained in the next slide…………



Observation and Application:

Fluorescence is the absorption of “invisible” light energy by a material capable of transforming it and emitting it at wavelengths visible to the human eye. Simply put, it is the process of converting ultraviolet light to visible light.

In wood, fluorescence is a species-dependent phenomenon which results from the natural presence of fluorescent extractives in some types but not others. In this activity, organic solvents were used to draw out wood extractives into solution, and then you tested the extract solution for fluorescence by excitation with a UV light.

In a naturally fluorescent material, chemicals (hydrogen, for example) absorb the UV light and transform the energy so that the light emitted from the material is within our visible range. The emitted light is seen as a particular color.

Fluorescence can be used to identify chemicals, light watch dials, kill harmful bacteria, create light in fluorescent light bulbs, and distinguish certain types of wood.

2. CELL ANATOMY

As you learned in Unit 1, Slide Set 2 Structure of Wood, wood is composed of several different cell types. The objective of this activity is to illustrate differences in wood cell shapes and sizes. Review slide 27 in Unit 1 Set 2 for a description of the various cells found in wood.

The types of cells found in a particular type of wood play a role in how it can be used. For example, long, thin fibers (cells) in softwoods make these species desirable for paper, especially where strength is needed. Shorter, flatter cells from hardwoods are good for writing papers where a smooth surface is more necessary than strength.

Supplies you will need:

- small specimens of softwood (such as pine, spruce, fir, cedar) and hardwoods (oak, ash, maple, hickory, cherry, poplar)   1/2” long
- knife or razor blades for splitting wood
- equal amounts glacial acetic acid and 6% hydrogen peroxide (enough to cover the splinters in a test tube to about twice their depth)
- test tubes and corks or screw tops
- cheesecloth
- oven capable of heating to 60° C
- food coloring or dye such as light green, methyl green, or safranin
- light microscope
- microscope slides and cover glasses
- eye dropper (pipette), glass rod, and dissecting needles
- glycerin (optional)

Activity*:

•split off small toothpick-size slivers of wood from a 1/2 inch long block (if pieces are split off along the grain, more cells will remain whole than by cutting across the grain)

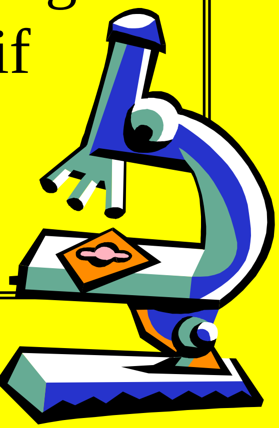
•place several pieces in a test tube and cover with a mixture that contains equal amounts of glacial acetic acid and hydrogen peroxide

•close the tube and place in an oven at 60° C for 24 hours

•remove the tube from the oven and stir the contents with a glass rod - the wood should break into individual cells; if separation is not complete, allow it to cook a little longer

* be sure to maintain adequate ventilation during this activity, you should perform the maceration in a fume hood if one is available

- when separation is satisfactory, allow the cells to settle to the bottom of test tube
- cover the open end of the test tube with cheesecloth and pour off the liquid, or remove with an eye dropper
- pulp should then be washed free of acid under cold running water - be careful not to loose too many wood cells
- the cells may be stained for better viewing by adding a few drops of dye to the last wash
- put small amounts of the macerated material on glass slides with an eye dropper and carefully tease apart with dissecting needles into a uniform dispersion, add a drop of glycerin if available, and place a cover slip on top
- view the temporary mount with a microscope



Observation of cell morphology:

1. In softwoods:

a. most of the cells are relatively uniform in type and shape; the long, slender cells (ave. 3 mm long) are the tracheids

b. ray cells are much different from the longitudinal cells - they are very short, brick shaped and they run radially in a tree stem

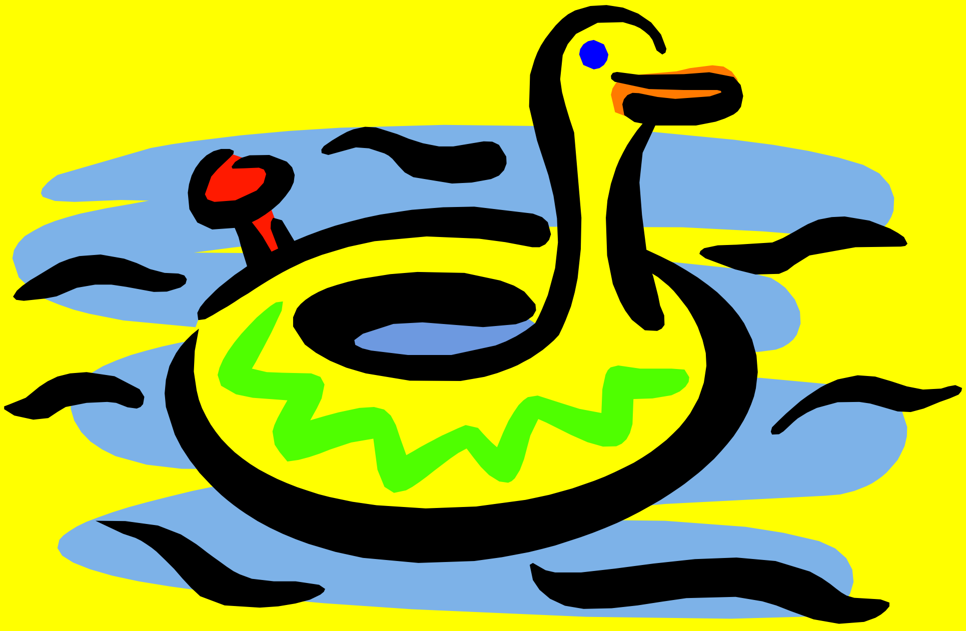
2. In hardwoods:

a. there is considerable more variety in cell type and size; for example, vessel segments, fibers, parenchyma, and tracheids are all found

b. note the brick-shaped cells, parenchyma, which are rather similar in shape to ray cells

c. note the differences among hardwoods, especially in vessel segment size and end connectivity

d. notice the numerous pits that cover the sides of the cells



3. HYGROSCOPICITY

<u>Ad</u>sorption is a process by which the surface of a material attracts moisture from the air. It differs from **<u>ab</u>sorption** which is the uptake of liquid due to physical contact with the liquid (like a sponge). A material which is capable of adsorption is said to be **hygroscopic**. A fundamental characteristic of wood is its hygroscopicity, i.e., its ability to attract moisture from the air. This property is traceable to the basic chemical structure of wood.

The amount of moisture adsorbed by wood can be expressed as the moisture content. Moisture content, calculated as a percentage of the oven-dry weight of wood is:

$$\% MC = \left(\frac{\text{weight of wood plus water} - \text{weight of dry wood}}{\text{weight of dry wood}} \right) \times 100$$

$$= \left(\frac{WW - DW}{DW} \right) \times 100$$

Where **% MC** is the percent moisture content of the wood;

WW is the "wet weight" or simply the weight of the wood (which contains adsorbed water) at a condition other than oven dry;

and

DW is the oven dry weight of the wood----the wood only, no water (determined by drying the wood in an oven at 105^{o}C until no water remains and the weight of the block no longer changes).

Supplies you will need:

•4 different aqueous salt solutions with a concentration that will give the desired vapor pressure of water in a closed container held at 20º C

use the following chemicals to achieve the desired relative humidity at 20ºC:

- •$MgCl_2$ for 33% RH (Magnesium Chloride crystals)
- •$MnCl_2$ for 54% RH (Manganese Chloride crystals)
- •NaCl for 76% RH (Sodium Chloride crystals or granular)
- •KNO_3 for 95% RH (Potassium Nitrate crystals)

•4 glass containers or bottles with lids or use small desiccators if available

•4 wood blocks (about 1” x 1” square and 2 inches long), all the same kind and from the same board if possible

•oven to dry wood blocks (needs to reach 105° C)

•balance (scale) and string or cord

Activity:

You will prepare four containers, each of which will contain a chemical solution that creates a different moisture environment inside the container. This moisture environment can be described by the relative humidity (RH%) which is a measure of the amount of moisture in the air. A higher RH% means there is more moisture in the air at a given temperature.

First dry the wood blocks in an oven at 105°C for 24 hours and record the dry weight (DW) in the chart.

Prepare the saturated salt solutions by mixing the salt crystals with water. Keep adding salt until it no longer dissolves in the water. Then, add another small amount to be sure you have a saturated solution.

Fill each glass container about half full with one of the salt solutions and label with the target relative humidity.

Tie a string around a wood block tightly and suspend the block over the solution. Allow the string to extend over the container rim and then close the container. Be sure the wood block does not contact the solution.

Remove and weigh the blocks every day for several days. Record this weight as the wet weight (WW) in the chart.

Activity continued:

At the end of the week (or equilibration period if the weight is still changing), remove each sample from its container, and record the final weight.

Using the %MC equation, the “wet weights” (WW) which you recorded for a week, and the “dry weights” (DW) which you determined at the start of the experiment, calculate the %MC of each sample as it has equilibrated in the container.

Example of a data chart for this activity:

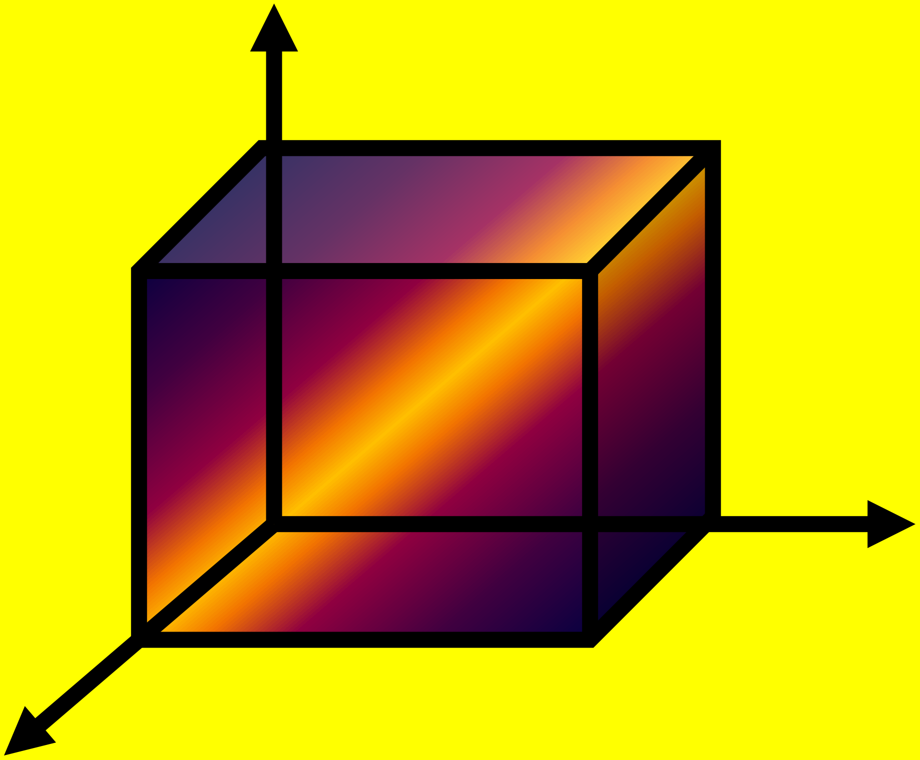
			Wet Weights (WW)					
Sample	RH%	DW	1	2	3	4	5	%MC
1	33							
2	54							
3	76							
4	95							

Observation and Application:

What is the relationship between time, RH% in the container, and %MC of the wood blocks? Sketch a graph of RH% vs. %MC to see the relationships.

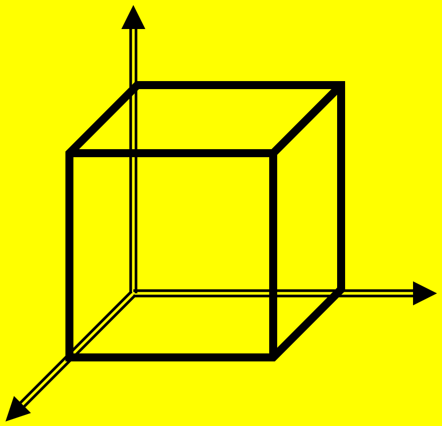
Since wood is hygroscopic, it changes in moisture content as the moisture environment in the air around it changes. This is important because as the moisture content of wood changes, it changes in dimensions (swells or shrinks), the mechanical properties change, and other physical properties are affected.

Therefore, proper use of wood products requires an understanding of their interaction with moisture.

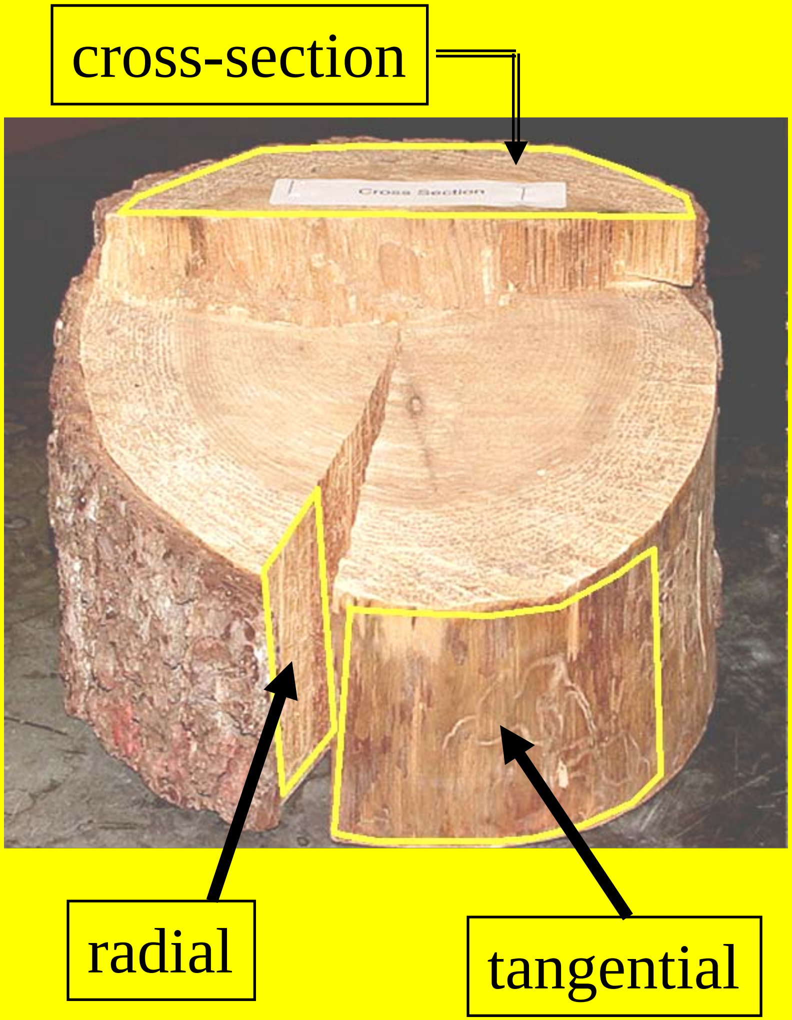


4. ANISOTROPY

Many materials have mechanical properties which are the same in all directions throughout the material. Such a material is said to be **isotropic**. Examples of isotropic materials are steel, concrete, and plastic. The mechanical properties of wood, however, vary with the direction in which a load or force is applied. Wood, therefore, is described as an **anisotropic** material.



When you look at the end of a log, that surface is the **cross section (X)**. If you then peeled off the bark from the log, you would see the **tangential (T) surface**, so called because this surface is tangent to the circular annual rings in the tree stem. If you then cut out a pie-shaped wedge of wood, you would expose the **radial surface (R)** as you cut toward the center along the radius of the log. These are the three primary surfaces of wood as shown in the figure to the right.

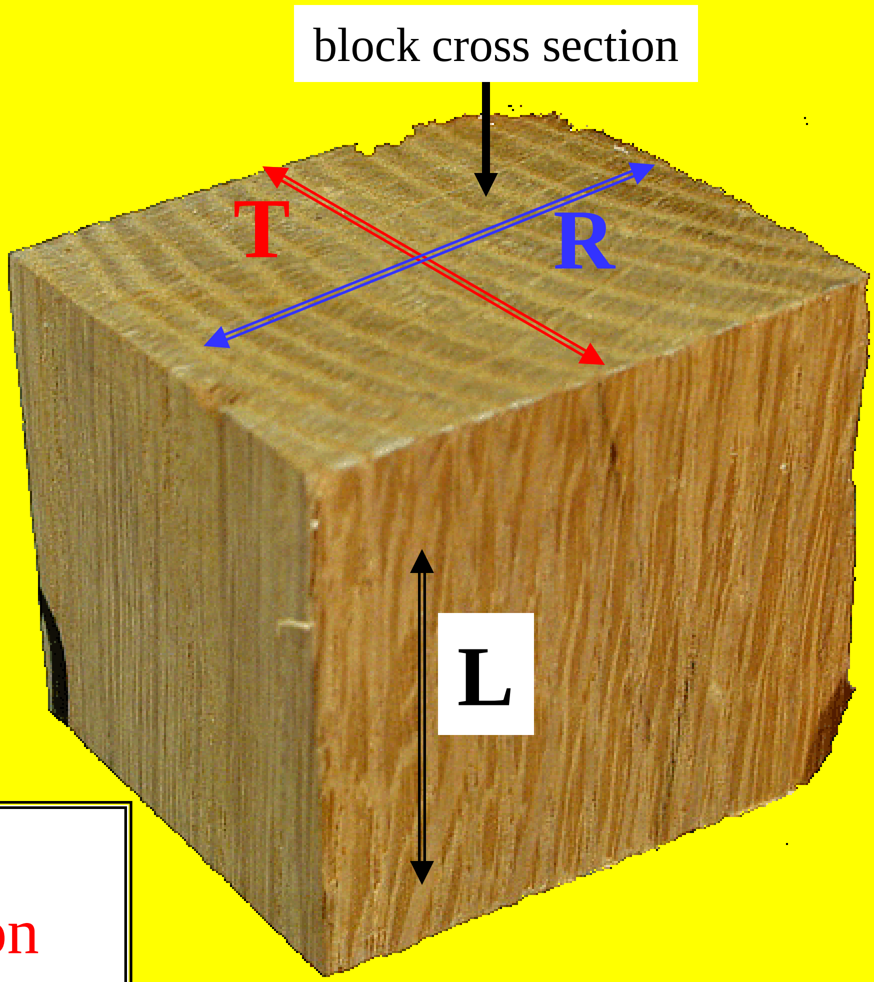


Due to the way cells are formed in a tree stem, wood has 3 structural directions-the **radial**, the **tangential**, and the **longitudinal** direction.

The tangential direction is parallel to the growth rings.

The radial direction is parallel to the wood rays.

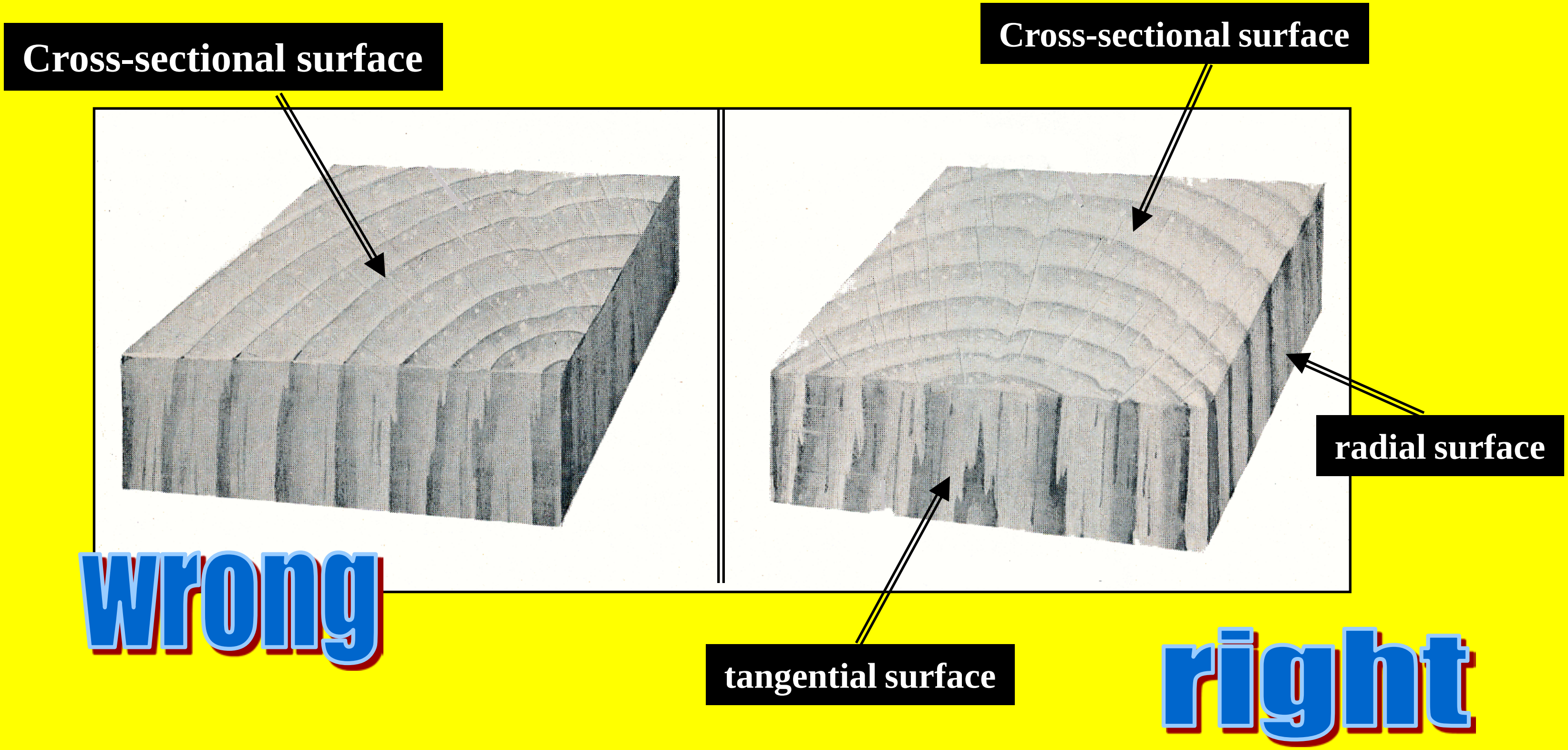
The longitudinal direction is parallel to the wood cells (the grain).



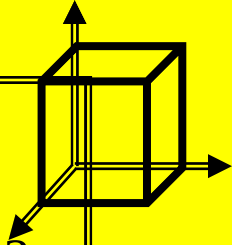
R = Radial direction
T = Tangential direction
L = Longitudinal direction
(aka grain direction)

Supplies you will need:

- samples of a variety of high and low density woods 2” x 2” x 2”, cut so that the 3 primary surfaces of wood are parallel with each side of the wood cube (see the next slide for an example)
- ruler or calipers
- basin of water
- oven for drying the wood



The wood blocks must be cut so that the growth rings appear as in the specimen at ***top RIGHT***, and *not* as in *top left*.



Activity:

This exercise is designed to show the different properties in each of the 3 wood directions - **L**ongitudinal, **R**adial, and **T**angential.

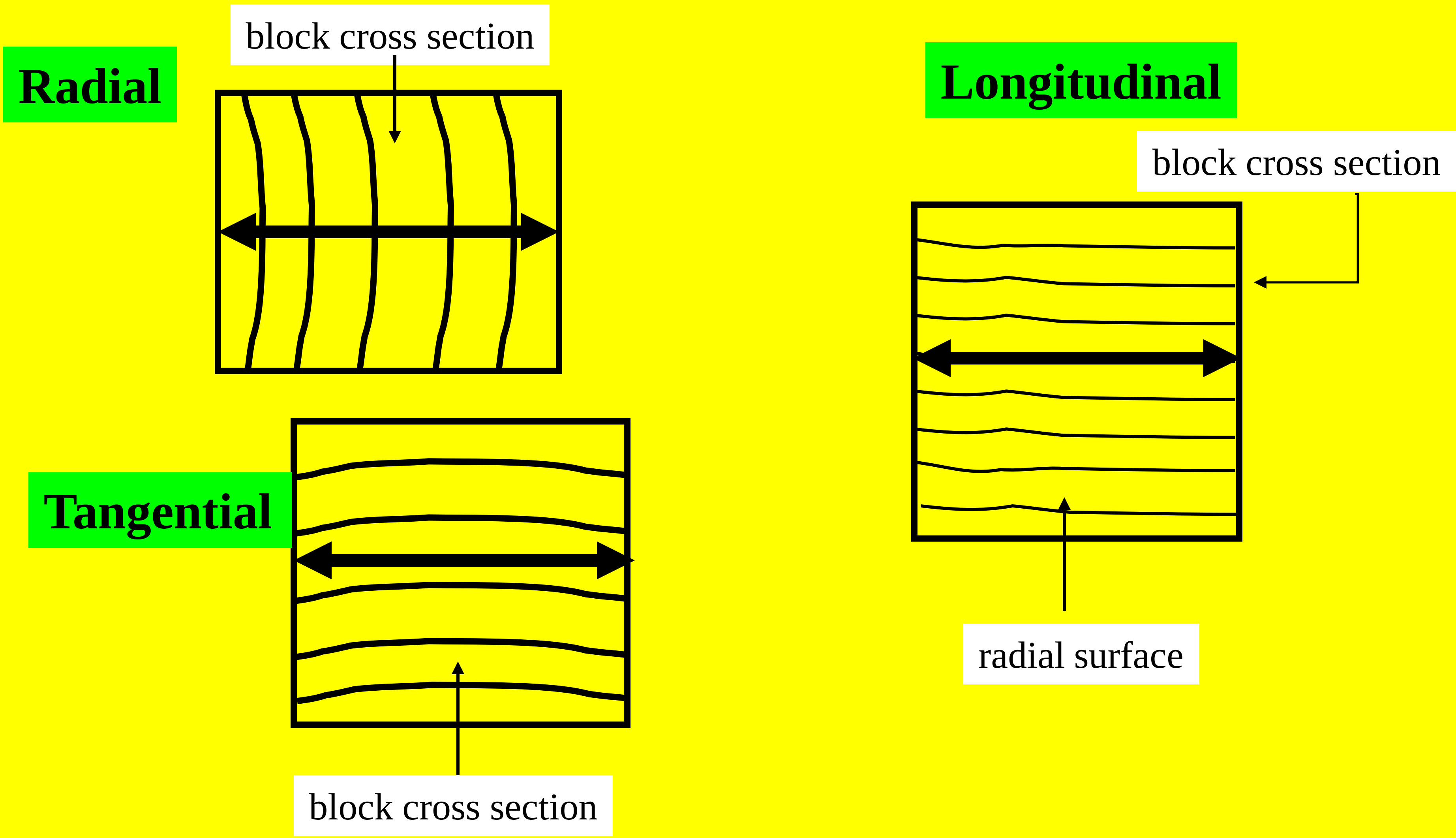
Thorough soak the specimens in water 24 hours. Wipe with a cloth, weigh, and measure the dimensions in each of the 3 directions (R, T, and L) as illustrated in the next slide. Record the wet dimensions in the chart.

Next place the specimens in an oven and dry 24 hours at 105° C or until they reach a constant weight. Then remeasure and record the dimensions.

Percent shrinkage in each direction is calculated as:

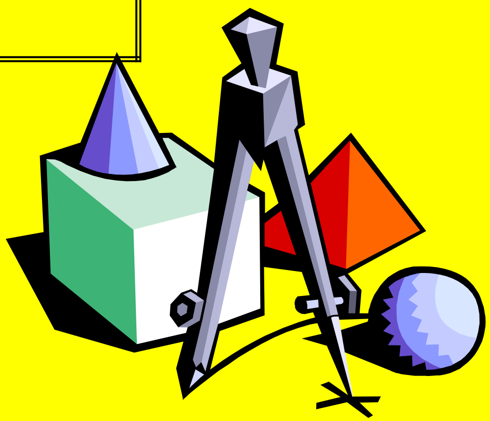
$$\text{Percent shrinkage} = \left(\frac{\text{wet dimension} - \text{dry dimension}}{\text{wet dimension}} \right) \times 100$$

arrows indicate what surface and distance to measure for each dimension



Results chart for anisotropy activity

Sample Direction	Wet dimension (mm)	Dry dimension (mm)	Shrinkage (%)
Longitudinal			
Tangential			
Radial			



Observation and Application:

Does the percent shrinkage vary with the wood direction? What is the reason for the differences? (hint: think wood cell arrangements) Can you think of situations in which this would be an advantage or a disadvantage?

If a variety of ring widths and species were used throughout the class, results from the group can be compared to show the variation among blocks of the same species, and between species. You should also have discovered that different amounts of shrinkage are to be expected along each direction in the same piece of wood and that different woods have different shrinkage capacities.

An understanding of the anisotropy of wood is of fundamental importance for all those who use wood.

5. Specific gravity[1]

(aka relative density)

[1] original source: USDA Forest Service, Forest Products Lab.

Classroom Demonstrations of Wood Properties.

1969 PA-900, Madison, WI

The concept of specific gravity comes from Archimedes' principal which showed that an object floating in water was being held up by a force equal to the weight of water displaced.

With wood, specific gravity is a measure of the amount of cell wall material in a piece. It is a useful indicator of strength properties and of suitability for various uses. Specific gravity is sometimes called "relative density".

Heavy woods, such as Douglas-fir, southern yellow pine, and oak, are used for heavy construction, while lighter ones, white pine or aspen for example, are desirable where load bearing is not the prime consideration.

This activity's objective is to define specific gravity and to show how specific gravity varies among species.

Supplies you will need:

- wood specimens 1 x 1 x 10 inches of white pine, southern pine, oak, and aspen (or a variety of high and low density woods, review the SG ruler in Unit 2 Slide Set 1 for examples)
- 500-cc graduated cylinder
- drying oven
- balance (scale)
- ruler

Activity*:

The method used here to determine specific gravity is called the flotation method, because the value is found from the amount of the specimen below the surface when it is floating in a liquid.

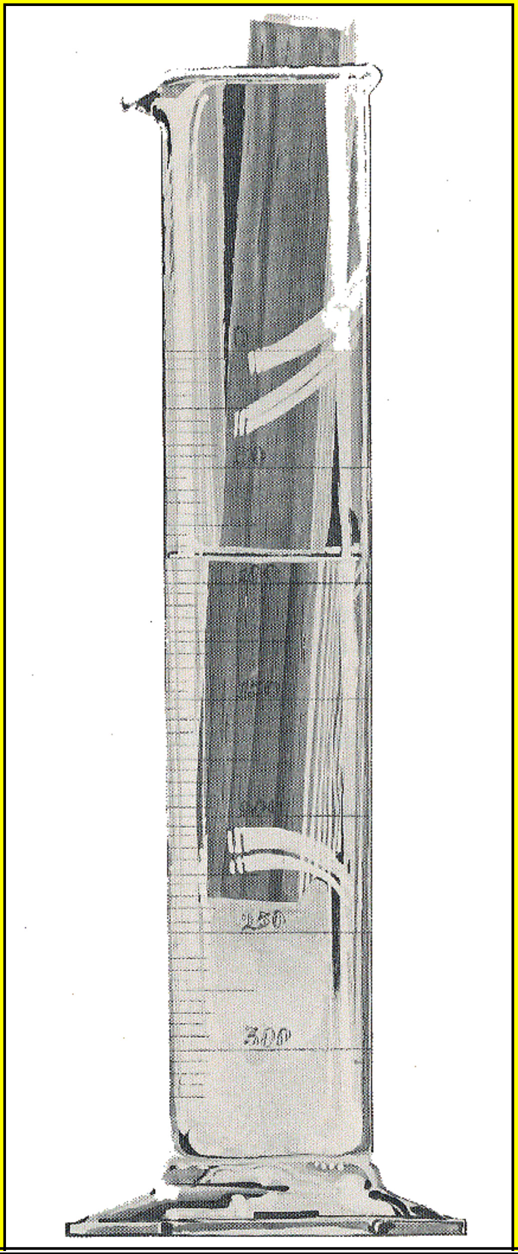
First, place the wood samples in an oven at 105°C overnight to remove excess moisture. Remove each specimen from the oven, weigh it, replace in the oven for about 2 hours and re-weigh. Repeat until each specimen reaches a constant weight, indicating that as much moisture as possible has been removed. The sample is then ready to be placed in the cylinder.

= =

*it might be desirable for the instructor to have dried the specimens prior to start of class

A graduated cylinder is suggested, but any vessel in which the sample is forced to float upright can be used. The cylinder should contain enough water to float a specimen upright with its top above the cylinder.

Next, gently lower the specimen into the water, taking care not to allow it to sink too deeply. When it has reached its floating level, withdraw the specimen from the water and measure the length of the sample which was under water. Record your results in the chart at the end of this activity.



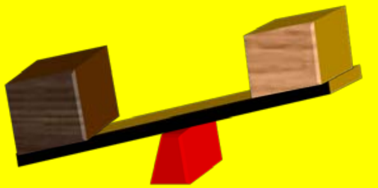
A tall glass cylinder is necessary for the specific gravity test, so that the specimen will float almost upright, giving a water mark at approximately a right angle to the length of the specimen.

Observation and Application:

Specific gravity of an object is obtained by dividing the weight of the object by the weight of an equal volume of liquid. It can be calculated using the following equation:

$$\text{specific gravity} = \frac{\text{weight of object}}{\text{weight of equal volume of water}}$$

Any liquid may be used, but water is the most common.



Recall that the concept of specific gravity comes from Archimedes' principal that showed that an object floating in water was being held up by a force equal to the weight of water displaced. If a sample sank to where the surface of the water coincided with the top of the sample, the specific gravity would be 1.0. Thus for the sample by our formula,

$$\text{Specific gravity} = 10/10 = 1.0$$

Let us assume that the specimen sinks only 4 inches into the water, that is, the weight of the specimen is supported by the force of 1 x 1 x 4 = 4 in^3 of water. Thus, by the formula,

$$\text{Specific gravity} = 4.0/10.0 = 0.4$$

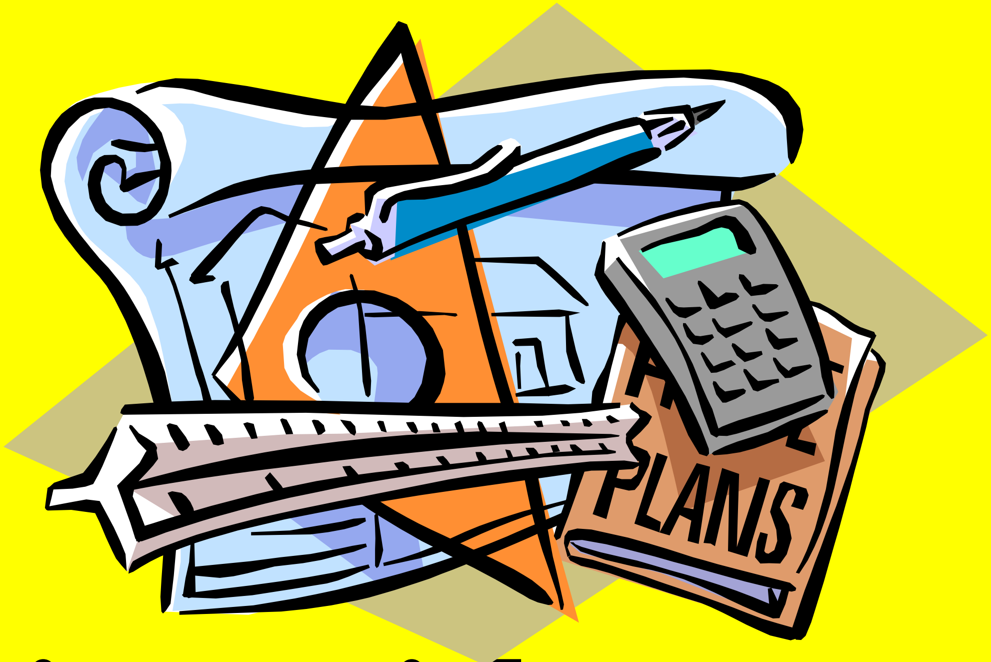
This is the specific gravity of the entire wood, that is, the cell walls and the spaces in the cells. This value varies for different woods because some woods have more air space or more wall material than others. The weight, or density, of the cell wall is the same for all woods, about 1.5. While this value is constant, the amount of cell wall material in a definite volume of wood varies considerably.

Specific gravity can also be thought of as the ratio of the density of a material to the density of water. With wood, it provides a relative value for describing the amount of cell wall material present in a particular volume of wood. This is particularly helpful since wood obtains its properties from the cell wall characteristics (including the relative amount of wall and lumen space).

Thus specific gravity, or relative density, serves as a predictor for estimating performance of a particular wooden member or the comparative behavior of different types of wood. It is one of the most commonly measured and widely used properties of wood.

EXAMPLE Results Chart for specific gravity activity

Wood type	Length under water	Length of specimen (10”)	Specific gravity (length/length)
1			
2			
3			
4			



6. Engineering with Wood[1]

[1] original source: USDA Forest Service, Forest Products Lab.

Classroom Demonstrations of Wood Properties.

1969 PA-900, Madison, WI

We have utilized wood’s unique and first-rate mechanical properties since tools were first crafted. From primitive times to today, wood remains the construction material of choice. Wood's enduring use in structures can be traced to many characteristics including ease of fabrication and conversion, favorable strength to weight ratio, impact resistance, dimensional stability, extreme versatility, and sustained availability. It's natural beauty and warmth is unmatched by other architectural materials.

Wood's mechanical properties make it a material that can be used to construct a variety of structures ranging from conventional residential buildings to modern large-scale structures like domes, bridges, or industrial complexes. World-wide, more buildings are constructed with wood than any other structural material.

Wood is available for structural applications in many forms. The most obvious is sawn lumber, which is wood that has been manufactured by simply cutting it directly from a log. Other structural materials such as glulam beams and arches start as lumber and then undergo additional processing. Engineered wood products are available for structural applications including structural composite lumber, structural-use panels such as plywood and oriented strandboard, and manufactured components such as trusses.

A better understanding of the mechanical properties of wood, lumber, plywood, and the other engineered wood products will enable you to utilize the full range of possibilities with wood materials.

Two experiments are described next that will (A) show the differences between nailed and glued wood beams and (B) show the differences between plywood and solid wood.

Supplies you will need:

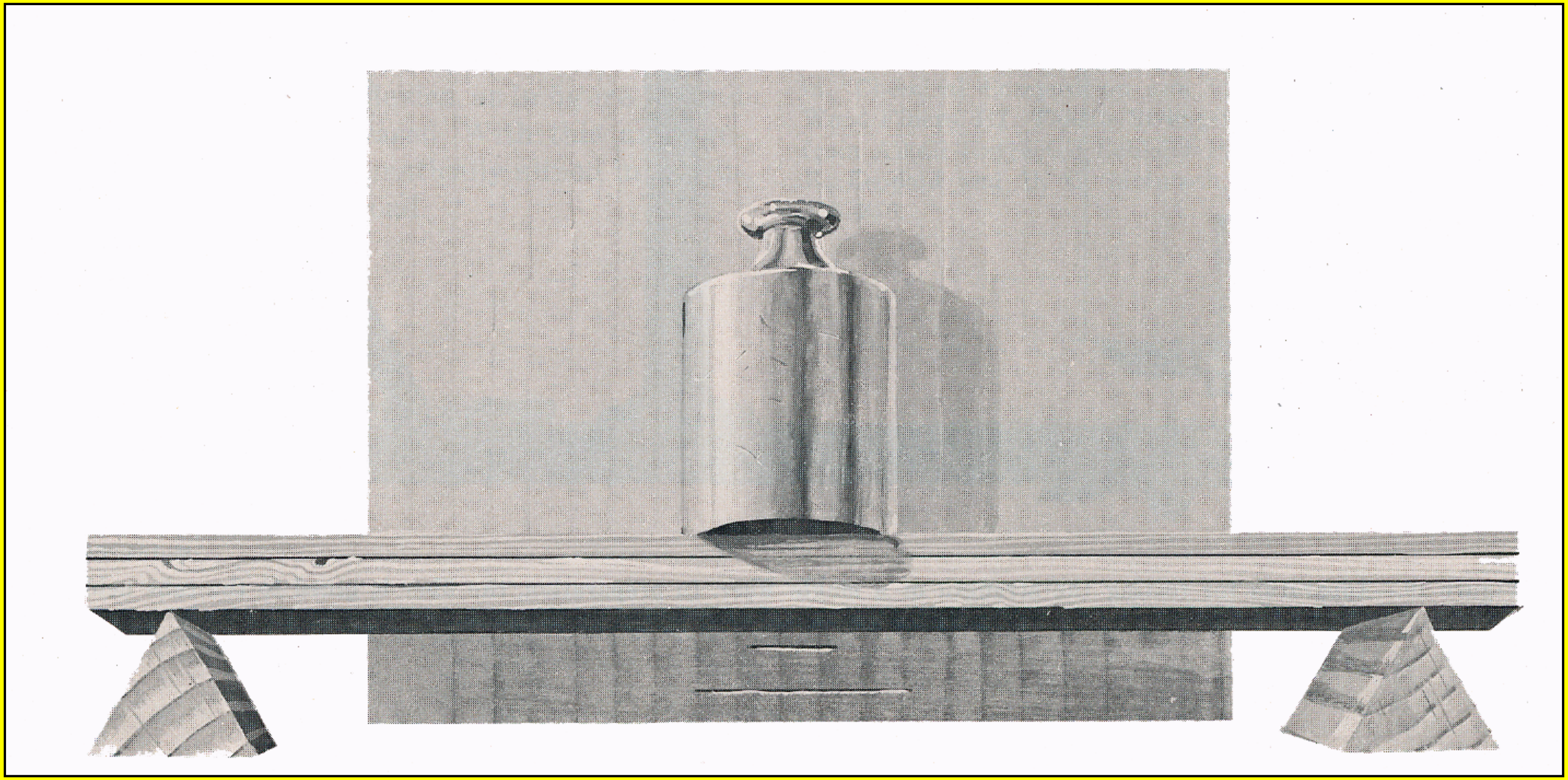
<u>Experiment A – Why Use Glue?</u>

- 9 strips of softwood (¼ x 1 x 18 inches)
- hammer, nails, & glue (ordinary wood glue will work fine)
- clamps
- 2 supports
- light colored cardboard backdrop
- 5000-gram weight

Activity:

Experiment A - Why Use Glue?

- take 3 of the strips & nail them together, one on top of the other
- take 3 other strips, glue them together, one on top of the other, clamp, and allow the glue to set (follow glue manufacture's instructions for application, clamping, and curing)
- place the remaining 3 strips, one on top of the other, across the supports, put the weight in the middle, mark the level of the bottom of the beam on the backboard (see figure on next slide), measure the distance of the mark from the bottom of the card
- replace the 3 single strips with the nailed assembly, apply the weight, measure and mark the bottom of the beam
- repeat with the glued beam
- record all your measurements on the chart



In this illustration, the weight is shown on the glued beam. The marks showing the limit of bending for the separate pieces and for the nailed beam are seen below the beam on the backboard.

You can now fill in a chart similar to this one below:

Beam type	**Deflection**
separate pieces	
nailed beam	
glued beam	

Observation and Application:

The three loose strips bend most, the nailed beam does not bend as far, and the glued beam bends least. In the first case, there is little support because the loose strips act as individual pieces. When nailed, there is greater unity, and when glued, it is as though a solid piece of wood were used.

Glued beams, or glued-laminated (glulam) beams as they are called in industry, are strong and can be made very large. Because they are made of many pieces of wood glued together, they can be made in almost any shape or size the engineer may want, while retaining the strength of solid wood.

glulam beam

Supplies you will need:

Experiment B – Why Use Plywood?

- 5 strips of oak (1/8 x 3 x 3 inches - oak veneer is available at home improvement stores, hardware stores, or from catalogs)
- 2 pieces of solid oak (3 x 3 x 5/8 inches)
- waterproof glue
- hammer and clamp
- sharp-pointed nails
- basin of water
- caliper or dial gauge

Activity:

Experiment B – Why Use Plywood?

•glue the 5 thin sheets of oak together with waterproof glue, making sure that the grain directions run at right angles to each other in adjoining sheets, as shown in the next slide

•clamp and allow the plywood to set completely following the manufacturer's instruction

•next hammer nails near an edge of the plywood and do the same with one of the solid oak pieces, observe if splits occur on nailing

•now measure the 3 dimensions (thickness, width, and length) with a caliper or dial gauge and note the size of the dry plywood and the solid oak block; record these dry dimensions in the chart

•thoroughly soak both for at least 6 hours and remeasure the dimensions; record the wet dimensions in the chart and compare the dimensions before and after soaking

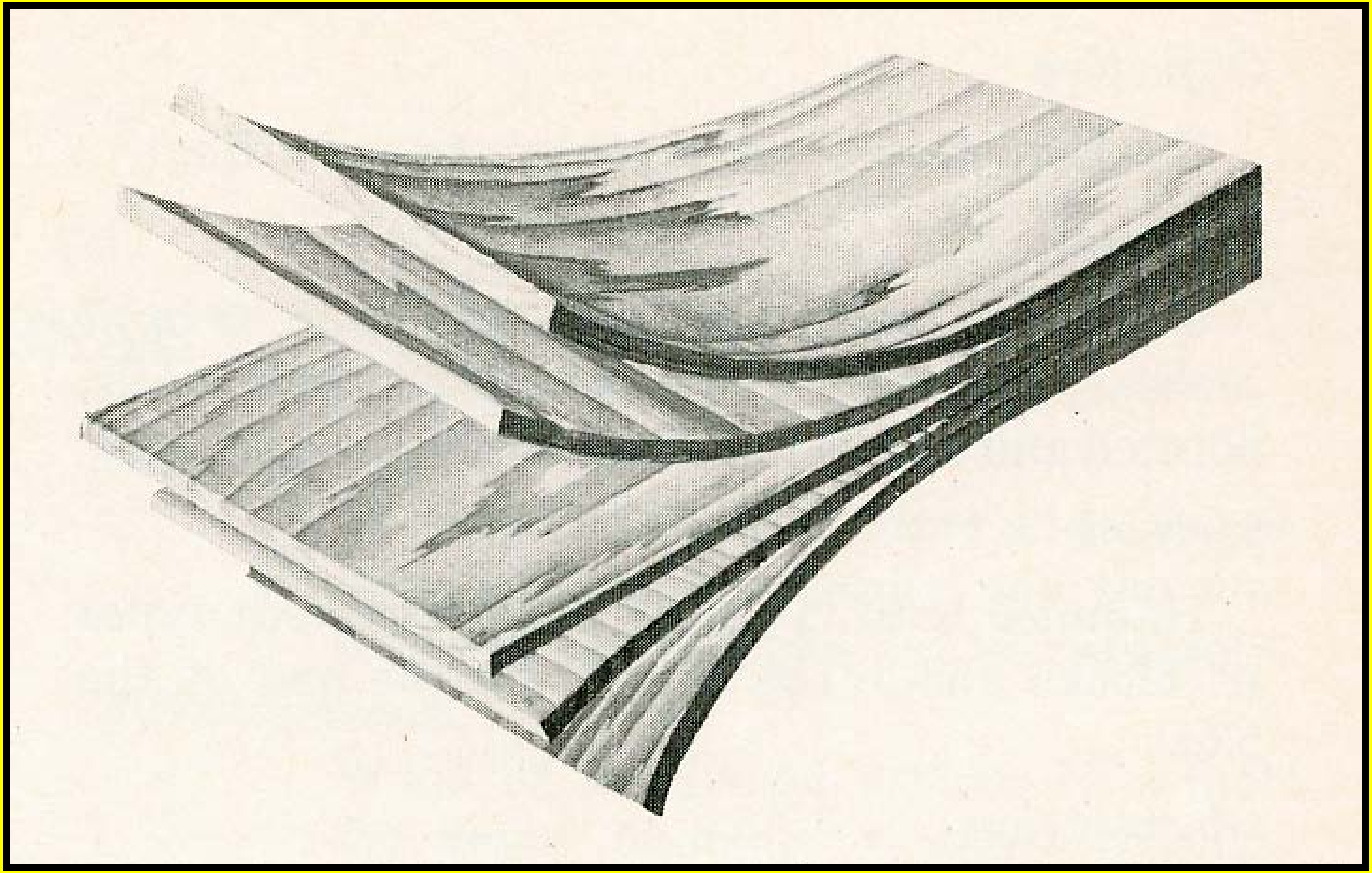


Diagram showing alternation of grain direction with each layer in plywood.

EXAMPLE Results Chart for Plywood

Sample type	Wet dimension	Dry dimension	Swelling (%)
solid wood			
plywood			

$$\text{Percent swelling} = \left(\frac{\text{wet dimension} - \text{dry dimension}}{\text{dry dimension}} \right) \times 100$$

Observation and Application:

The plywood does not split on nailing, but the solid block does. In the plywood, the cells cross each other at right angles in the different layers; when a crack begins, it is stopped by the cells which run across it in the next layer. There is less resistance to crack development in the solid block, however.

When soaked, the plywood increases in size less than the solid wood block. Again the cells running at right angles to each other limit the amount of expansion, while there is no such counteracting effect in the solid block.

Plywood is a good example of taking wood apart and putting it back together to make a more useful product. The oak plywood holds regular nails better than the solid block, and does not shrink and swell as much. For some purposes this makes it easier to use than solid boards, and also provides larger flat surfaces.

Additional information concerning careers in the general field of wood science and technology, including those in production management, process engineering, technical sales, and product development can be obtained by contacting:

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