

COURSE OUTLINE

FORS 340-- FOREST PRODUCTS MANUFACTURING

3 Credits

- Instructor:** Ed Burke
- Office:** Stone Hall 105 Phone: 243-5157
- Course Schedule:** Lecture Tuesday, 18:00.to 20:50, FORESTRY 301
Laboratory Wednesday and Thursday, 14:00 to 17:00, Meet in either Forestry 301 or Stone Hall 102 (Wood Lab)
- Special Lab Tour:** Date to be announced: All-day lab trip to see Flathead Valley lumber, plywood, cross-laminated timber production
- Suggested/ Optional Text:** *Forest Products and Wood Science* by Bowyer, Shmulsky and Haygreen, 5th. Edition, Blackwell Publishing, Ames, Iowa. 2007.
- Outcomes:** At the end of the semester, successful students will be able to:
- Verbally and diagrammatically describe the different layers of the cell walls of Gymnosperm and Angiosperm xylem.
 - Recognize the three anatomical directions and three anatomical planes of wood specimens in hand or under the microscope
 - Verbally and diagrammatically describe the microscopic and macroscopic a tree's above and below-ground body and appendages
 - Identify several commercial wood products and describe the raw materials and processes that produce them
 - Determine the green lumber target size required to produce lumber of standardized dimensions given species, sawing, planing and drying parameters and desired lumber grade
 - Using ASTM standards, prepare specimens for static bending evaluation, perform the standard static bending tests and determine the as-tested strength values as specified in the standards.
 - Determine the dry and wet-basis moisture contents of wood and wood products using gravimetric and electrical resistance methods, as outlined in the ASTM standards.
 - Determine the specific gravity and density of woods using ASTM standardized methods.
 - Explain the correlation between tree growth characteristics and the mechanical and physical properties of wood.

Manufacturing Facility Tours during Laboratory:

Field trips and exercises showing different forest product manufacturing will be conducted during laboratory periods throughout the semester and one special all-day Monday trip, Some laboratory exercises will also be held in the classroom and in the Wood Science Laboratory, Stone 102. Any changes in the specific details of timing and conduct of these laboratory sessions will be announced in class.

- 1 Introduction; Plant Cell Wall Architecture and Fundamental Properties.**
Lectures: Discussion of the chemical constituents and the architecture of the plant cell wall. Lecture will continue with a detailed discussion of the cells and their arrangement in both angiosperms and gymnosperm secondary xylem cells and their different characteristic features and morphology. **Laboratory;** Continued discussion of Wood morphology and microscopic anatomy and how they relate to wood properties.
- 2 Tree and Wood Structure and Fundamental Properties.** **Lectures:** Discussions of anatomical directions and planes in the tree and xylem, as well as covering the fundamental wood structure and properties. We will also discuss and work problems in determining wood density, moisture content, shrinking and swelling. **Laboratory;** Students will determine wood moisture content, density, specific gravity and total shrinkage in the longitudinal, radial, tangential directions, as well as volumetric shrinkage. Each student will be responsible for producing a laboratory write-up with results of their investigation. Students will be assigned times to report to Wood Lab to make their measurements.
- 3 Anatomy & Identification of Gymnosperm and Angiosperm Wood:** **Lectures:** Quiz over basic tree morphology, anatomical directions and planes, wood-liquid relations. Fundamental wood anatomy of Gymnosperms will be presented using macro and micrographs from archival and live sources. Cell types, arrangements, wall thicknesses and effects of growth conditions on wood structure will be presented. **Laboratory;** Students will learn fundamentals of wood identification using both macroscopic (hand lens) and microscopic means. Students will learn how to use both macroscopic and microscopic identification keys.
- 4 Review, Lecture Exam #1 and Lab Exam #1:** **Lectures:** Review of lecture material from Weeks 1-3. 1-hour Exam covering material from Weeks 1 through 3. **Laboratory;** Exam covering lab exercises in fundamental properties and wood identification. Practical microscopic and gross identification of unknown wood specimens.
- 5 Lumber Production:** **Lectures:** Lumber manufacturing and recovery factor, between and within board variation, various growth and manufacturing characteristics and fundamental lumber grading will be covered. Lumber production flow charts and equipment. Lumber grading and marketing. Determination of log scale, lumber sizes and marketing **Laboratory;** Meet outside the Wood Lab's roll-up door no later than 14:00. Lumber milling exercise at Wood Science Laboratory's sawmills at Lubrecht Forest. Students will be shown and operate both circular and band headsaw mills. **NO SHORTS OR SANDALS!!** Wear forestry field clothes, including work gloves, long pants, button shirts, boots.
- 6 Lumber Drying and Laminated Solid Wood:** **Lectures:** Discussion of manufacture and use of laminated beams, laminated veneer lumber (LVL), cross-laminated timbers and panels (CLT), houselogs for the log home industry. **Laboratories:** Discussion and demonstration of sawblades, planers, lumber drying and grading. Introduction to other solid wood products such as post and poles, utility poles, treating methods and maintenance.
- 7 Veneer and Plywood:** The discussion shall focus on the rotary and sliced veneer and plywood industry, including the types of adhesives used to bond these products. Other veneer products, such as Laminated Veneer Lumber will be introduced. **Laboratory.** Teams of 2-3 students will select veneer plies, spread adhesive, layup a panel, press and trim their own

plywood. Teams will be scheduled for lab instruction sessions and panel layup operations.

- 8 Review, Lecture Exam #2 and Lab Exam #2:** **Lectures:** Review of lecture material from Weeks 5-7. 1-hour Exam covering material from Weeks 5 through 7. **Laboratory;** Exam covering lab exercises in Lumber Manufacture, Lumber Drying, Solid and laminated wood products, veneer and plywood. Samples of the different products, raw materials and tools/machinery will be identified.
- 9 Composites and Engineered Structural Panels and Beams:** Manufacturing processes involved in manufacture of particleboard, medium density fiberboard (MDF) oriented strand board (OSB), structural composite lumber (SCL) and Hardboard. **Laboratory;** Tour of Roseburg Forest Products particleboard plant in Missoula. **NO SHORTS OR SANDALS!!** Wear forestry field clothes, including long pants, button shirts and boots. Hardhats and other Personal Protective Equipment (PPE) will be provided.
- 10 Flathead Valley All-Day Trip: Monday (06:30 – 18:00)** trip to Flathead Valley Wood Products mills. View manufacturing processes used in manufacture of cross-laminated timbers, plywood and lumber. Bring sack lunch, drinks and snacks, and wear field clothing. Hardhat and other PSE provided. Meet no later than 06:30 at Campus Security to load up in University Vehicles and return at 18:00 hrs. Full field gear including hardhat and other PSE required. **Lecture:** Thermo-mechanical, semi-chemical chemical pulping processes, recycled paper technology and kraft paper production presented. **Laboratory:** No Wednesday or Thursday laboratory session this week
- 11 Election Day Holiday:** **Lecture:** No lecture this week. **Laboratory:** No laboratories this week.
- 12 Physical Properties of Wood:** A discussion of wood's orthotropic behavior and its properties along the three principal axes of the tree and solid wood. We will also discuss and work problems in determining wood density, moisture content, shrinking and swelling. **Laboratory;** Students will determine wood moisture content, density, specific gravity and total shrinkage in the longitudinal, radial, tangential directions, as well as volumetric shrinkage. Each student will be responsible for producing a laboratory write-up with results of their investigation. Students will be assigned times to report to Wood Lab to make their measurements.
- 13 Thanksgiving Holiday:** **Lecture:** No lecture this week **Laboratory:** No laboratories this week.
- 14 Mechanical Properties of Wood:** A discussion of the mechanical properties of solid wood, as well as the physics and engineering used in their evaluation. Introduction to standardized mechanical test methods, and explanation of static bending testing of dimension lumber tested as a simply-loaded joist. **Laboratory;** Mechanical Testing Exercise. Groups of 3-4 students will use the Tinius Olsen universal testing machine to conduct static bending testing of full-size lumber following the methods of ASTM Standard D-193. Calculation of moisture content, specific gravity, Modulus of Elasticity and Modulus of Rupture will be made by each group, with each student performing their own calculations and writing a full report of the exercise in accordance with ASTM D-193.

15 Lecture and Laboratory Final; Lectures: A 2-hour lecture final covering entire course, but 75% of the questions will pertain to material covered since Examination #2. **Laboratory:** 2-hour laboratory final, covering the gross and microscopic identification of selected species of wood as well as the identification of specimens of wood products and various raw materials, finished products, tools and equipment used in the manufacture of the products covered during the semester. Some simple mathematical computations (moisture content, specific gravity etc.) similar to those on the lecture final and Examinations #1 & 2 may also be present on the Lab Final

Special All-Day Laboratory Trip: Special, day-long trip to a mill complex(es) in w. Montana to see lumber, plywood and medium density fiberboard plants. Leave Forestry School Parking Lot at 06:30 return at 18:00. Bring sack lunch and snacks. **NO SHORTS OR SANDALS!!** Wear forestry field clothes, including long pants, button shirts, boots. Bring civilian clothes for the ride home, if desired, but have your field clothes on when we leave so we can get out of the vans and go right into a tour.

Laboratory sessions for the course will consist of both exercises held inside the Wood Science Laboratory as well as field trips to the Lubrecht Forest and Roseburg Lumber Co.’s Missoula particleboard plant and the Flathead Valley.

- **No sandals or shorts are permitted on field trips.**
- **Hard hats, eye & hearing protection and safety vests will be furnished and WORN at all times when on plant grounds and buildings.**
- **Field boots and gloves, in addition to the other Personal Protective Equipment, are strongly advised, especially for the Lubrecht field trip and the mechanical testing exercises.**

Course grading will be as follows:

(2) 1.5-hr. lecture examination during Week #5	300 pts.
(1) 2-hr. lecture final examination in Week #9	200 pts.
(1) 2-hr laboratory final examination	200 pts.
Total for Course	700 pts.

A = 90.00+ %; B = 80.00 – 89.99 %; C = 70.00 – 79.99 %; D = 60.00 – 69.99 %; F < 60.00 %

Student Conduct Code

All students must practice academic honesty. Academic misconduct is subject to an academic penalty by the course instructor and/or a disciplinary sanction by the University. All students need to be familiar with the [Student Conduct Code](http://life.umt.edu/vpsa/student_conduct.php). http://life.umt.edu/vpsa/student_conduct.php.

Important Dates Restricting Opportunities to Drop a Course:

To 15 th instructional day	Students can drop classes on CyberBear with refund	18 September is the last day for unrestricted drops
16 th to 45 th instructional	Drop requires form with instructor and advisor signature, a \$10 fee from registrar’s office, student will receive a ‘W’ on transcript, no refund.	21 September through 30

day		October
Beginning 46 th instructional day	Students are only allowed to drop a class under very limited and unusual circumstances. Not doing well in the class, deciding you are concerned about how the class grade might affect your GPA, deciding you did not want to take the class after all, and similar reasons do not qualify as “very limited and unusual circumstances”. If you want to drop the class for these less serious sorts of reasons, make sure you do so by the end of the 45 th instructional day of the semester.	2 November

Class Attendance Policy

- Students who are registered for a course but do not attend the first two class meetings may be required to drop this course. This rule allows for early identification of class vacancies to permit other students to add classes. Students not allowed to remain must complete a drop form or drop the course on the Internet (<http://cyberbear.umt.edu>).
- Students are expected to attend all class meetings and complete all assignments for this course. Student may be excused for brief and occasional absences for reasons of illness, injury, family emergency, religious observance or participation in a University sponsored activity. (University sponsored activities include for example, field trips, ASUM service, music or drama performances, and intercollegiate athletics.) Students shall be excused for military service or mandatory public service.
- Students incurring an excused absence will be allowed to make up missed work when done in a manner consistent with the educational goals of this course.
- Students expecting to incur excused absences should consult with the instructor early in the term to be sure that they understand the absence policies for this course.

Determining a Sample's Moisture Content and Specific Gravity

This exercise is designed to teach the methods used in determining moisture content, size and shape after drying and green lumber target size

Step 1. Measurement of Mass/Weight

- Determine and record the current (green) masses of samples with the laboratory balance.

Step 2. Measurement of Volume

- Set beaker of water on balance and tare balance to 0.0
- Affix block to end of knife blade with rubber stopper on handle
- Immerse block deep enough in water to cover block, placing rubber stopper in clamp on vertical support.
- Immediately read value of mass of displaced water and record
- Remove block from knife tip and repeat for second sample block
- Record the values for green volume in Measurements Table

Step 3. Drying Sample Blocks

- Place identified blocks in oven set at 105°C.
- Following removal of all moisture (block loses no more mass), the blocks are ready for re-measuring

Step 4. Obtain OD Mass/Weight and Volume

- Remove OD blocks from oven and immediately weigh on balance to obtain OD mass/weight
- Record OD weight of each block in Measurements Table
- Determine OD volume using methods of Step 2. and record values in Measurements Table

Step 5. Determination of Wood Moisture Content.

- Moisture Content (%) = $((\text{Green wt.} - \text{Oven Dry wt.}) / \text{Oven Dry wt.}) \times 100$

Step 6. Determination of Specific Gravity

- Specific Gravity is determined by computing the mass and volume of a block (green, oven dry or in-service conditions). Most handbooks use Green Volume and Oven Dry weight to compute the specific gravity using the following formula: $SG = \text{Density of Wood} / \text{Density of Water}$. The density of wood is computed by determining the wood's weight and volume. Therefore, knowing that the density of water in the metric system is 1 gm. / 1cc (ml) or 62.4 lbs./ft³, the specific gravity is computed for the weight and volume using the combination of wt. / volume.
- Determine Specific Gravity using Green Volume and Green wt.
- Determine Specific Gravity using Green Volume and OD wt.
- Determine Specific Gravity using OD Volume and OD wt.

Why are these values different? What is the most useful value to use to estimate the effect of moisture content and specific gravity on a structural member?

WARNING!

Always make immersion volume measurement AFTER making mass measurements

1. **Make green and dry mass (weight) measurements for both Sample A and Sample B. and record in Mass and Volume Table.**
2. **Make green and dry volume measurements of A and B by immersion and record in Mass and Volume Table.**

Mass and Volume Measurements Table				
	Immersion Volume (measure after measuring mass) (cc)		Block Weight/Mass (measure first before measuring immersion volume) (grams)	
	Sample Block "A"	Sample Block "B"	Sample Block "A"	Sample Block "B"
Value @ Test (green)				
Value when Oven Dry				

3. **Using formula for determining Moisture Content, compute and record the Moisture Content of Sample A and Sample B. Complete table by computing the means of these values**

Moisture Content Computation Table		
Sample Block "A"	Sample Block "B"	Mean

4. **Using formulae in Specific Gravity Table's first column, compute and record the Specific Gravity for Sample A and Sample B. You will compute SG for test (green) wt./green volume, test wt./OD volume and, finally, OD wt./OD vol. Complete table by computing the means of these three values**

Specific Gravity Computation Table			
Mean Specific Gravity Formula	Result for Sample Block "A"	Result for Sample Block "B"	Mean
Wt. @ test./ vol. @ test			
Wt. @ test /OD vol.			
OD wt./OD vol.			

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Example of Determining the Finished Size of a Lumber Specimen Following Drying

This exercise is designed to teach the methods used in determining size and shape of solid wood after drying.

How to Determination of Shrinkage

Given:

Specimen is a green, quarter-sawn interior north Douglas-fir “2 x 12, with as-sawn dimensions of 12.000” wide x 2.000” thick x 96.000” long. Assume the FSP = 30%, the starting MC is > 60%, and the desired ending MC = 19%

- Determine the species of the specimen
- Determine the ring orientation (wide face/narrow face; radial and tangential directions)
- Determine the amount of shrinkage expected based on Wood Handbook tabulated values for each direction and face on the sample
- Determine or set beginning and ending moisture contents, and Fiber Saturation Point
- Assume linear relationships for all 4 shrinkage values (fiber saturation point to 0% MC); Longitudinal, Radial, Tangential and Volumetric
- Calculate % shrinkage for each anatomical direction in the specimen using the tabulated values for the species’ shrinkage and the assumed/given fiber saturation point, beginning and ending moisture content
- Wood Handbook equation 3-4

$$S_m = S_o ((FSP - M)/FSP)$$

where:

S_m = Shrinkage (%) from the green condition to moisture content M (<30%)

M = desired ending moisture content (<30%)

S_o = total % shrinkage (radial, tangential or volumetric)

GENERAL SOLUTION for Part 1:

Using Wood Handbook values for shrinkage of the species of interest, Douglas-fir, the assumed Fiber Saturation Point, and the preselected final moisture content, determine the estimated loss of width and thickness, in inches, and subtract that from the green dimensions.

Specific solution:

First step; obtain shrinkage data for interior north Douglas-fir from Table 3-5 of the Wood Handbook

Radial = 3.8%, Tangential = 6.9%, Volumetric (not needed in this problem) = 10.7%.

Longitudinal shrinkage (not needed in this problem) is often insignificant (0.1-0.2%) in normal, non-juvenile wood.

You can disregard longitudinal shrinkage in most cases.

Second step; compute shrinkage in width and thickness, based on the beginning dimensions, the assumed FSP, the stated ending MC and the handbook values of radial and tangential shrinkage applied to the width and thickness properly.

- A. Determine the % width shrinkage when dried to new moisture content:

$$\begin{aligned} S_{m(\text{radial})} &= 3.8\% ((30\% - 19\%) / 30\%) \\ &= 3.8\% (0.3666) \\ &= \underline{1.39\% \text{ loss of width due to shrinkage}} \end{aligned}$$

- B. Determine the % thickness shrinkage when dried to new moisture content:

$$\begin{aligned} S_{m(\text{tangential})} &= 6.9\% ((30\% - 19\%) / 30\%) \\ &= 6.9\% (0.3666) \\ &= \underline{2.53\% \text{ loss of thickness due to shrinkage}} \end{aligned}$$

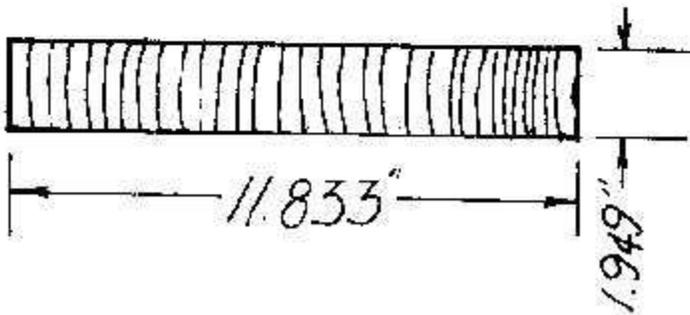
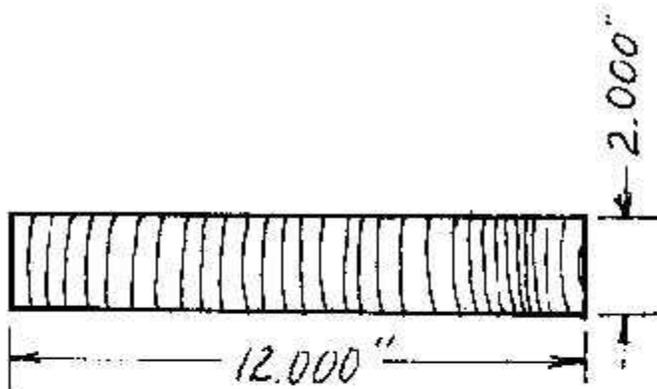
Third step; compute the dry cross-section dimensions of dried lumber specimen

A. Determine the dry width @ :

$$\begin{aligned} \text{Width @ 19\%} &= \text{green width} - (\text{green width} \times .0139) \\ &= \text{green width} \times (1 - .0139) \\ &= 12.000 \times 0.9861 \\ &= \mathbf{11.833''} \end{aligned}$$

B. Determine the dry thickness:

$$\begin{aligned} \text{Thickness @ 19\%} &= \text{green thickness} - (\text{green thickness} \times .0253) \\ &= \text{green thickness} \times (1 - .0253) \\ &= 2.000 \times 0.9747 \\ &= \mathbf{1.949''} \end{aligned}$$



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Moisture Content Determination and Lumber Shrinkage Problem #1

- I. Given a sample of sample of a package of Douglas-fir/western larch lumber that has a green mass of 31.26 grams while displacing 62.52 cc, and has an oven-dry mass of 25.44 grams and OD volume of 58.6 cc, what is its beginning moisture content (%) and density (gms. / cc), and what is its density at OD conditions (gms/cc & lbs. / ft³? The density of water is equal to 1 gm/cc or 62.4 lbs./ft³. If specific gravity, G, is equal to the density of wood over the density of water, what is the specific gravity of the lumber specimen at the time of sampling (green condition) and at oven dry (0%)?
- II. Given the preceding sampling results for moisture content, density and specific gravity, estimate the weight of 1,000 bd. Ft. of 2"x6"x10" Douglas-fir/western larch at 22.88% mc. (Hint: Specific gravity of a specimen multiplied times the density of water (lbs./ft³) will yield the average density of the lumber in lbs./ft.³)

Solution to Problem #1, Part I:

1. Compute the original moisture content of the sample using the following formula:

$$\begin{aligned} \text{MC (\%)} &= ((\text{Green wt.} - \text{OD wt.}) / \text{OD wt.}) \times 100 \\ &= ((31.26 \text{ gms.} - 25.44 \text{ gms.}) / 25.44 \text{ gms.}) \times 100 \end{aligned}$$

$$\underline{\text{MC}_{\text{original}} = 22.88\%}$$

2. Compute the metric density of the sample at green condition using the following method:

$$\begin{aligned} \text{Density} &= \text{Mass}_{\text{green}} / \text{Volume}_{\text{green}} \\ &= 31.26 \text{ gms.} / 62.52 \text{ cc.} \end{aligned}$$

$$\underline{\text{Density}_{\text{green}} = .50 \text{ gms/cc}}$$

3. Compute the metric density of the sample at OD condition using the same method but using OD mass and volume:

$$\begin{aligned} \text{Density} &= \text{Mass @ OD} / \text{Volume @ OD} \\ &= 25.44 \text{ gms.} / 58.6 \text{ cc.} \end{aligned}$$

$$\underline{\text{Density}_{\text{OD}} = .43 \text{ gms/cc}}$$

4. Compute the specific gravities using the following formula:

$$\begin{aligned} \text{Specific Gravity (G)} &= \text{Density of wood} / \text{Density of water} \\ G_{\text{green}} &= (.50 \text{ gms/cc}) / (1 \text{ gm./cc}) \end{aligned}$$

$G_{\text{green}} = .50$ Note: G has no units. It is a ratio of densities.
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$$G_{\text{dry}} = (.43 \text{ gms/cc}) / (1 \text{ gm/cc})$$

$G_{\text{dry}} = .43$

Solution to Problem #1, Part II:

1. Compute the density, in lbs./ft.³, of the lumber sample @ 22.88% MC.

$$\begin{aligned} \text{Density (lbs./ft}^3\text{) @ green condition} &= G_{\text{green}} \times \text{Density of Water} \\ &= .50 \times 62.4 \text{ lbs./ft}^3 \end{aligned}$$

$$\underline{\text{Density}_{\text{green}} = 31.2 \text{ lbs./ft.}^3}$$

2. Determine the actual volume of a finished 2 x 6 x 10' piece of lumber using standard dimensions:

If nominal thickness is 2", the actual thickness is 1.500"

If nominal width is 6", the actual width is 5.5"

If nominal length is 10', the actual length is 10' x 12"/lineal foot = 120.000"

$$\text{Volume}_{\text{actual}} = (\text{Actual Thickness (in.)} \times \text{Actual Width (in.)} \times \text{Actual Length (in.)}) / 1,728 \text{ in}^3/\text{ft}^3$$

remember that $1 \text{ ft.}^3 = 12'' \times 12'' \times 12''$

$$1 \text{ ft.}^3 = 1,728 \text{ in.}^3$$

$$\text{Volume}_{\text{actual}} = (1.5 \times 5.5 \times 120) / 1,728$$

$$\text{Volume}_{\text{actual}} = \mathbf{0.573 \text{ ft.}^3/\text{piece}}$$

3. Determine the nominal (nom.) board-foot volume of each piece of lumber (volume used for buying and selling):

$$\begin{aligned} \text{Volume}_{\text{nom}} &= (\text{nom. thickness (in.)} \times \text{nom. width (in.)} \times \text{nom. length (ft.)}) / 12 \\ &= (2'' \times 6'' \times 10') / 12 \end{aligned}$$

$$\text{Volume}_{\text{nominal}} = \mathbf{10 \text{ bd. ft. / piece}}$$

4. Determine the actual weight of each piece of dry, finished lumber:

$$\begin{aligned} \text{Weight} &= \text{actual volume of each piece (ft}^3\text{)} \times \text{Density (lbs./ft}^3\text{)} \\ &= 0.573 \text{ ft}^3 \times 31.2 \text{ lbs./ft}^3 \end{aligned}$$

$$\text{Weight} = \mathbf{17.88 \text{ lbs. / piece}}$$

5. Determine the number of pieces in the load

$$\begin{aligned} \# \text{ of pieces} &= \text{nominal volume of load} / \text{nominal volume of each piece} \\ &= 1,000 \text{ bd. Ft.} / 10 \text{ bd. Ft./piece} \end{aligned}$$

$$\# \text{ of Pieces} = \mathbf{100}$$

6. Determine the weight of the entire load;

$$\text{Total weight} = \text{weight of 1 piece} \times \# \text{ of pieces}$$

$$\text{Total weight} = 17.88 \text{ lbs. /pc.} \times 100 \text{ pcs.}$$

$\text{Total estimated weight of the load} = \mathbf{1,788 \text{ lbs.}}$

Lumber Shrinkage, Weight and Cost Problem #2

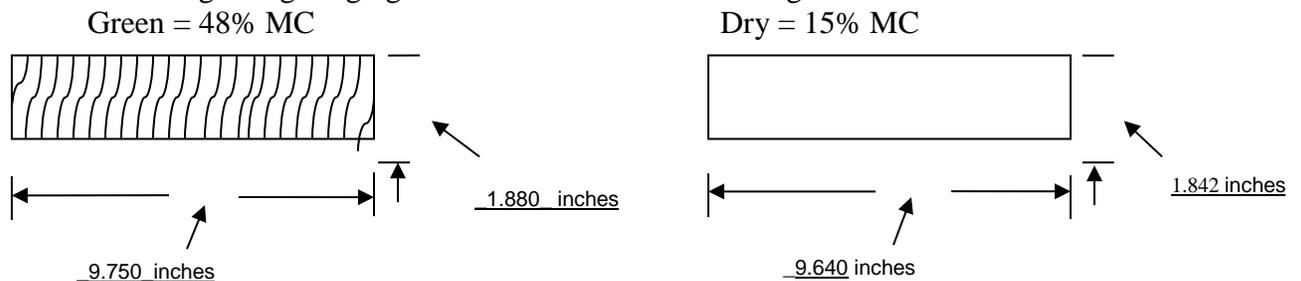
- I. Calculate the approximate dry (15% MC) width and thickness ($\pm .001''$) of a green, quartersawn sawn (55% MC), redwood 2" x 10" x 16' whose actual rough green-sawn dimensions are 9.750" x 1.880" x 192.000". Be sure to draw the correct growth ring orientation in the rectangles on the answer sheet, and place the beginning and end dimensions in the places provided.
- II. Determine the approximate dry (10%MC) weight (lbs.) of one (1) piece of this lumber.

III. Determine the cost of one (1) piece of this lumber

- The Fiber Saturation Point (MC where shrinkage begins) is 30%.
- The dry Target Moisture Content is 15%.
- Total volumetric shrinkage = 9%.
- Total tangential shrinkage = 5.5%
- Total radial shrinkage = 3.1%
- Total longitudinal shrinkage = .1%
- Show your work below the diagrams in order to obtain credit.
- Specific gravity of this lumber at 15% MC = .40
- Cost of this lumber is \$975.00 / Mbf (thousand board feet)
- Density of water = 1 gm./ 1cc or 62.4 lbs./ft.³

Solution to Problem #2, Part I:

1. First, draw in the growth rings in the correct orientation in both rectangles. Then fill in the beginning rough green dimensions in the left diagram.



2. Determine dry dimensions of lumber

$$\text{Dry Size} = \text{Green Size} - [\text{Green Size} \times (((\text{FSP} - \text{MC}) / \text{FSP}) \times \text{Total Shrinkage})]$$

$$\begin{aligned} \text{Width} = \text{Radial} &= 9.750 - [9.750 \times (((30 - 19) / 30) \times .031) \\ &= 9.750 - 0.110 \end{aligned}$$

$$\boxed{\text{Width} = 9.640''}$$

$$\begin{aligned} \text{Thickness} = \text{Tangential} &= 1.880 - [1.880 \times (((30 - 19) / 30) \times .055)] \\ &= 1.880 - 0.038 \end{aligned}$$



$$\text{Thickness} = 1.842''$$

3. Make cost calculations using nominal size

$$\begin{aligned}\text{Cost/piece} &= \text{Bd.ft./piece} \times \text{cost/Bd. Ft.} \\ &= ((2 \times 10 \times 16)/12) \times (\$975/\text{Mbf} / 1000 \text{ Bd.ft.} / \text{MBF}) \\ &= 26.66 \text{ Bd. Ft.} / \text{piece} \times \$975 / \text{Bd. ft.}\end{aligned}$$

Cost/piece = \$26.00

4. Make weight calculations using actual size

$$\begin{aligned}\text{Weight/ piece} &= \text{Wood Density} \times \text{Volume /piece} \\ \text{Wood Density} &= \text{Wood Specific Gravity}_{\text{dry}} \times \text{Density of Water}\end{aligned}$$

$$\underline{\text{Wood Density} = .40 \times 62.4 \text{ lbs.} / \text{ft.}^3}$$

5. Determine wood density (lbs./ft³) using given specific gravity

$$\begin{aligned}\text{Wood Density} &= \text{Specific Gravity}_{\text{MC}\%} \times \text{Density of Water} \\ &= 0.40 \times 62.4 \text{ lbs./ft.}^3\end{aligned}$$

$$\underline{\text{Wood Density} = 24.96 = 25 \text{ lbs.} / \text{ft.}^3}$$

6. Determine the Volume / piece

$$\begin{aligned}\text{Volume / piece} &= [\text{Width (in.)} \times \text{Thickness (in.)} \times \text{Length (in.)}] / 1728 \text{ in.}^3 / \text{ft.}^3 \\ &= 11.362 \times 1.839'' \times (14' \times 12) / 1728\end{aligned}$$

$$\underline{\text{Volume / piece} = 2.031 \text{ ft.}^3 / \text{piece}}$$

$$\text{Weight/ piece} = 25 \text{ lbs./ft}^3 \times 2.031 \text{ ft}^3 / \text{piece}$$

Weight / piece = 50.78 lbs.
