COURSE OUTLINE
FORS 340-- FOREST PRODUCTS MANUFACTURING
Autumn Semester 2014
2 Credits

Instructor:	Ed Burke
Office:	Stone Hall 105 Phone: 243-5157
Course Schedule:	Lecture Tuesday, 17:45.to 20:40, Stone Hall, 112 Laboratory Wednesday and Thursday, 14:10 to 17:00, Meet in Stone Hall 102 (Wood Lab)
Special Lab Tour:	Monday, 15 September or 6 October. Plum Creek Lumber, Plywood and Medium Density Fiberboard Mills in Evergreen and Columbia Falls, MT 07:30 – 18:30.
Suggested/ Optional Text:	*Forest Products and Wood Science* by Bowyer, Shmulsky and Haygreen, 5th. Edition, Blackwell Publishing, Ames, Iowa. 2007.

Field trips and exercises showing different forest product manufacturing will be conducted during laboratory periods, throughout the semester. Some laboratory exercises will also be held in the classroom and in the Wood Science Laboratory, Journalism 102. Specific details of these laboratory sessions will be announced in class.

Week # TOPIC

1. **Introduction; 26 August; Wood Structure and Fundamental Properties.**

   We begin with 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; 27 & 28 August**: 2-person teams will determine wood moisture content, density, specific gravity and total shrinkage in the longitudinal, radial, tangential directions, as well as volumetric shrinkage. Each team will be responsible for producing a laboratory write-up with results of their investigation. Student teams will be assigned times to report to Wood Lab to make their measurements.

2. **Lumber Production; 2 September.**

   The team report of first laboratory's exercise is due at beginning of lecture. Lumber manufacturing and recovery factor, between and within board variation, various growth and manufacturing characteristics and fundamental lumber grading will be covered. **Laboratory; 3 & 4 September.** Meet outside the Wood Lab's roll- up door no later than 14:10. 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.

3. **No Class or Laboratory 9, 10 & 11 September**;

   Burke working in Colorado and Missouri.

4. **Special All-Day Laboratory Trip; Monday 15 September.**

   Special, day- long trip to Evergreen and Columbia Falls, MT to see lumber, plywood and medium density fiberboard plants. Leave Forestry School Parking Lot at 07:30 return at 18:30. 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.

4. Veneer and Plywood; 16 September.

Discussion focuses 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. **Regular Laboratory**; **11 & 12 September.** 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. NOTE:A rough draft of the report of the Lubrecht lumber production laboratory (primarily floor plan and flow charts of the two mills and the verbal write-up of the mill's History, employment, products, markets, process, costs and future outlook is due at the beginning of lecture.

5. Examination #1; 23 September; No laboratory this week:

2-hour written exam w. moisture content, shrinking and swelling, as well as lumber and plywood manufacturing flow diagrams, equipment identification and explanations, definitions, flow diagrams to draw. **Laboratory:** No laboratory activity this week.

6. Composites and Engineered Structural Panels and Beams; 30 September:

Manufacturing processes involved in manufacture of Particleboard, Oriented Strand Board and Hardboard. **Laboratory; 1 & 2 October.** Tour of Roseburg Forest Products particleboard plant in Missoula. NO SHORTS OR SANDALS!! Wear forestry field clothes, including long pants, button shirts, boots.

7. Special All-Day Laboratory Trip; Alternate Day. Monday 6 October.

Special, day-long trip to Evergreen and Columbia Falls, MT to see lumber, plywood and medium density fiberboard plants. Leave Forestry School Parking Lot at 07:30 return at 18:30. 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.

Mechanical Properties of Wood; 7 October:

Discussion of the mechanical properties of solid wood and the physics and engineering used in their evaluation.

Laboratory; 8 & 9 October: Mechanical Properties Exercise. Groups will conduct static bending testing of full-size lumber using the methods of ASTM Standard D-193. You will calculate moisture content, specific gravity, Modulus of Elasticity and Modulus of Rupture. Groups of 3-4 students will each prepare, test and summarize group testing results from a static bending test-to-failure.

8. Paper and Interesting Specialty Products; 14 October:

Laboratory: this week's laboratory to be announced.

9. Lecture Final Examination; 21 October:

A 2-Hour lecture final covering entire course, but 75% of the questions will pertain to material covered since Examination #1, including particleboard, fiberboard and other engineered panels, paper and, finally, mechanical properties. **Laboratory Final Examination; 21 October:** 1-hour laboratory final, immediately following lecture final. Examination will cover the identification of specimens of wood products as well as various raw materials, finished products, tools and equipment used in the of the products covered during the semester. Some simple mathematical computations (moisture content, specific gravity etc.) similar to those on the lecture final and Examination #1 may also be present on the Lab Final.

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.

- **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.**

Final reports on laboratory tours due at beginning of period. Final report collection will include the three Plum Creek facilities, Roseburg particleboard and the Mechanical Properties exercise will be due at the beginning of the final exam held in Week #9. The best way to approach plant reports is to assume you have been retained by an out-of-state forest products corporation interested in purchasing plants in Montana, and your tour is a fact-finding mission. Your primary job is to obtain the preliminary data needed to acquire the companies. As with all reports of this nature, thoroughness, brevity, clarity and accuracy are of utmost importance.
Several 3 1/4" x 4 1/4" or 4"x 5" color photos of the different phases of all operations are the mark of a good report. Again, the entire package of the mechanical properties lab exercise and the Plant Assessment Report will be submitted as a unit at the beginning of the final exam period.

Report Information

A floor plan is a map of the plant, with relative locations of the machinery shown in planar view. A flow chart shows the flow of raw material, residues (by type) and product from machine center to destination. Colored-coded flow arrows overlaid on the floor plan is a good way to show both products. The report should address the following items in Paragraph format:

- Parent Company History and Overview
- Plant History
- Concluding Prognosis including future plant changes, product line adjustments etc.

The report, due at the beginning of the final exam on 21 October, should address the following items in Bulleted format:

- Labor-number of employees, average wage, union or non-union
- Raw material form, species, collection radius, how purchased (whole sales or logs at the gate)
- General production process description, with clear referrals in the text to

embedded photographs and appended floor plan

- Plant products, their marketing, their approx. wholesale value

Course grading will be as follows:

(1) 2-hr. lecture examination during Week #5	150 – 200 pts.
(1) 2-hr. lecture final examination in Week #9	200 - 250 pts.
(1) 1-hr laboratory final examination	100 pts.
(1) Final Laboratory Report	150 pts.
Total for Course	**600 – 700 pts.**

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

- **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. The Code is available for review online at Student Conduct Code**

FORS 340--TIMBER HARVESTING AND FOREST PRODUCTS

Laboratory #1, Exercise #1
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 looses 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 (%)= ((Green wt. – Oven Dry wt.) / Oven Dry wt.) X 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 = Density of Wood / 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./ft^3, 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.			

FORS 340

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

$$S_m = S_o \left((FSP - M)/FSP\right)$$

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:

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

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

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

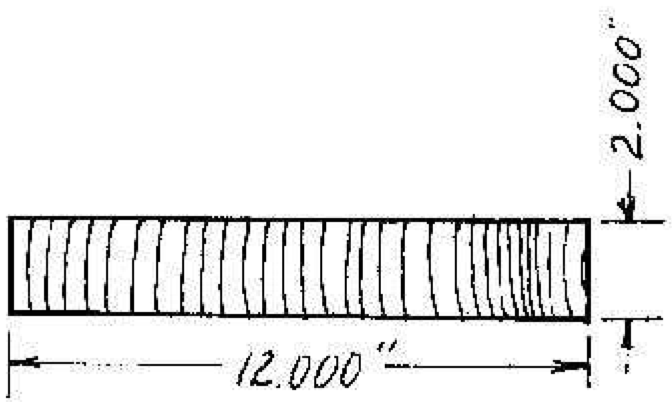
Third step; compute the dry cross-section dimensions of dried lumber specimen

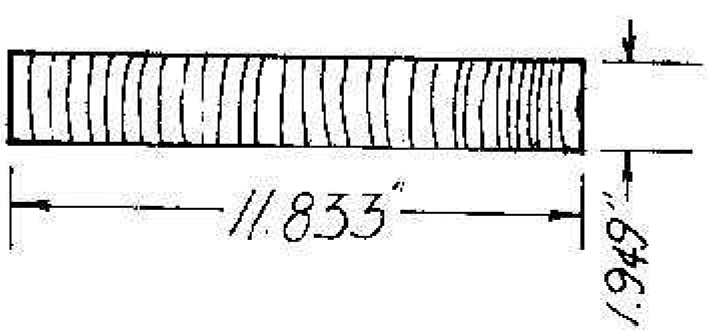
A. Determine the dry width @ :

Width @ 19% = green width – (green width x .0139)
= green width x (1 - .0139)
= 12.000 x 0.9861
=**11.833"**

B. Determine the dry thickness:

Thickness @ 19% = green thickness – (green thickness x .0253)
= green thickness x (1 - .0253)
= 2.000 x 0.9747
=**1.949"**





FORS 340
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. / ft^3? The density of water is equal to 1 gm/cc or 62.4 lbs./ft^3. 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./ft^3) 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:

MC (%) = ((Green wt. – OD wt.)/ OD wt.) x 100
= ((31.26 gms. – 25.44 gms.)/ 25.44 gms.) x 100

$MC_{original}$ = 22.88%

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

Density = $Mass_{green}$ / $Volume_{green}$
= 31.26 gms. / 62.52 cc.

$Density_{green}$ = .50 gms/cc

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

Density = Mass @ OD / Volume @ OD
= 25.44 gms. / 58.6 cc.

$Density_{OD}$ = .43 gms/cc

4. Compute the specific gravities using the following formula:

Specific Gravity (G) = Density of wood/Density of water
G_{green} = (.50 gms/cc) / (1 gm. /cc)

G_{green} = .50 Note: G has no units. It is a ratio of densities.

G_{dry} = (.43 gms/cc) / (1 gm/cc)

G_{dry} = .43

Solution to Problem #1, Part II:

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

   Density (lbs./ft^3) @ green condition = G $_{green}$ x Density of Water
   = .50 x 62.4 lbs. /ft^3

   Density $_{green}$ = 31.2 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"

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

remember that 1ft.^{3} = 12"x12"x12"
1 ft.^{3} = 1,728 in.^{3}
Volume $_{actual}$ = (1.5 x 5.5 x 120) / 1,728

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

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

   Volume $_{nom}$ = (nom. thickness (in.) x nom. width (in.) x nom. length (ft.)) / 12
   = (2" x 6" 10') / 12

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

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

   Weight = actual volume of each piece (ft^3) x Density (lbs./ft^3)
   = 0.573 ft^3 x 31.2 lbs./ft^3

   Weight = 17.88 lbs. / piece

5. Determine the number of pieces in the load

   # of pieces = nominal volume of load / nominal volume of each piece
   = 1,000 bd. Ft. / 10 bd. Ft./piece
   # of Pieces = 100

6. Determine the weight of the entire load;
   Total weight = weight of 1 piece x # of pieces
   Total weight = 17.88 lbs. /pc. X 100 pcs.

Total load weight = 1,788 lbs.

Total estimated weight of the load= 1,788 lbs.

Lumber Shrinkage, Weight and Cost Problem #2

I. Calculate the approximate dry (15% MC) width and thickness (± .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.

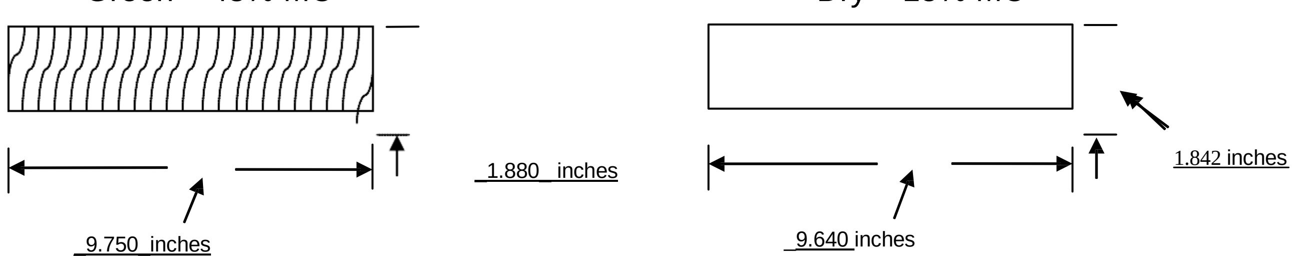
III. Determine the cost of one (1) piece of this lumber

- 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.

Green = 48% MC   Dry = 15% MC



2. Determine dry dimensions of lumber

Dry Size = Green Size- [Green Size x (((FSP-MC)/FSP) x Total Shrinkage)]

Width = Radial = 9.750 – [9.750 x (((30-19)/30) x .031

= 9.750 – 0.110

Width = 9.640”

Thickness = Tangential = 1.880 – [1.880 x (((30-19)/30) x .055)]
= 1.880 – 0.038

Thickness = 1.842"

3. Make cost calculations using <u>nominal</u> size
   Cost/piece = Bd.ft./piece x cost/Bd. Ft.
   = ((2 x 10 x 16)/12) x ($975/Mbf / 1000 Bd.ft. / MBF)
   = 26.66 Bd. Ft. / piece x $.975/ Bd. ft.

Cost/piece = $26.00

4. Make weight calculations using <u>actual</u> size
   Weight/ piece = Wood Density x Volume /piece
   Wood Density = Wood Specific Gravity $_{dry}$ x Density of Water

<u>Wood Density = .40 x 62.4 lbs. / ft.^{3}</u>

5. Determine wood density (lbs./ft^3) using given specific gravity

   Wood Density = Specific Gravity$_{MC\%}$ x Density of Water
   = 0.40 x 62.4 lbs./ft.^{3}
   <u>Wood Density = 24.96 = 25 lbs. / ft.^{3}</u>

6. Determine the Volume / piece
   Volume / piece = [Width (in.) x Thickness (in.) x Length (in.)] / 1728 in.^{3} / ft.^{3}
   = 11.362 x 1.839" x (14' x 12) / 1728

<u>Volume / piece = 2.031 ft.^{3} / piece</u>

Weight/ piece = 25 lbs./ft^3 x 2.031ft^3/piece

Weight / piece = 50.78 lbs.