Mechanics of Materials Laboratory Manual

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Contents

Experiment One: Creep Test on Wires 2
Creep Test Data Sheet 2
Experiment Two: Tension Test 4
Experiment Three: Compression Test on Wood 5
Experiment Four: Shear Force in Beams 8
Experiment Five: Torsion of Circular Sections 13
Experiment Six: Charpy Impact Test/Ductile to Brittle Transitional Temperature Test 18
References 20
Appendix 22
Wood Tables [1] 22
Tinius Olsen Manual 27

Experiment One: Creep Test on Wires

Reference: Chapter 15 pp. 261-273

Introduction

A loaded member will deform elastically if stressed below the proportional limit and will, theoretically, also deform in elastically over the plastic range if the load is kept on for some time. The amount of inelastic deformation will vary with the material composition, with time duration and magnitude of loading and with the temperature to which the member is exposed. Structural metals, for example, loaded at ordinary indoor/outdoor temperatures, creep so slowly that the effect can be neglected. Reinforced concrete will creep a noticeable amount in a few years.

We will test a lead-tin solder alloy, which will creep fast enough at room temperature to give measurable deformations during the time available to this course. The instructor will help the group set up the specimen; the students will read the data on every weekday according to some fixed schedule. Later in the semester, we will plot the data and discuss the results.

Laboratory Procedure

A piece of solder wire will be attached to a metal chuck. A weight will be attached to the other end. Be very careful not to kink or scratch the solder. Mark two narrow lines with a felt pen or tap, approximately 12 to 15 inches apart on the solder. Record the following data on a sheet posted near the specimen.

A. Type of solder alloy, if known
B. Original diameter
C. Weight placed on specimen
D. Date and time of reading
E. Distance between marks (used same measuring device each day)
F. Room Temperature
G. Name of the person taking the data

Note: It may be useful to mark the wire with a thin piece of tape or to secure the wire with one mark in the chuck. Over time, the sharpie mark might fade and may not be visible for accurate readings.

Report Procedure

A. Graph: Plot a graph of creep deformation versus time (in days); label on the graph the three stages of creep for constant load if they are evident.

B. Questions for you to consider when you are studying:
   1. Consider how variation in temperature might influence your creep deformation versus time curve. Was this significant in your actual experiment?
   2. Do our experiments involve "relaxation"?

Materials:

1. 50/50 tin-lead solder
2. Lead free solder
3. 95/5 tin-antimony solder

Loading Conditions:

Material/Alloy	Weight Applied		Temperature
	Group 1	Group 2	
50/50 tin-lead solder			Ambient laboratory temperature as recorded daily
Lead free solder			
95/5 tin-antimony solder			

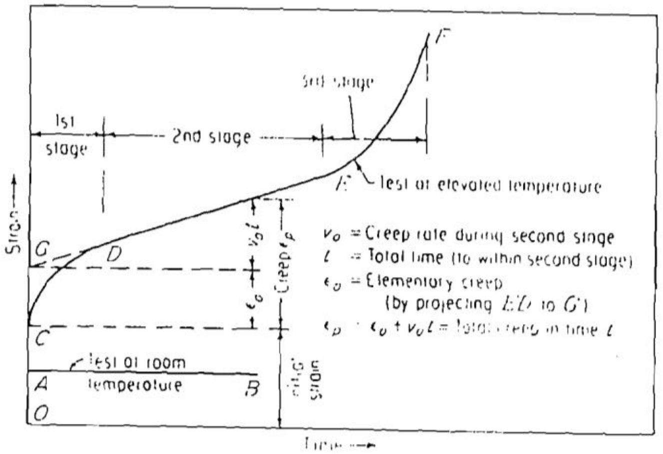


Figure 15.1 Strain-time curves at room and at elevated temperatures

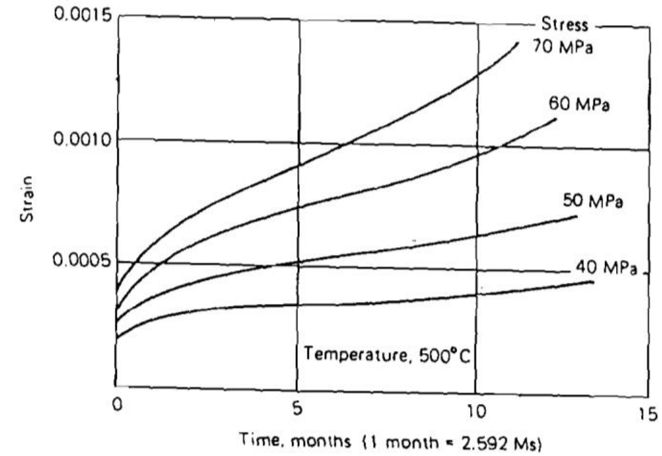


Figure 15.2 Creep curves for a typical carbon steel.

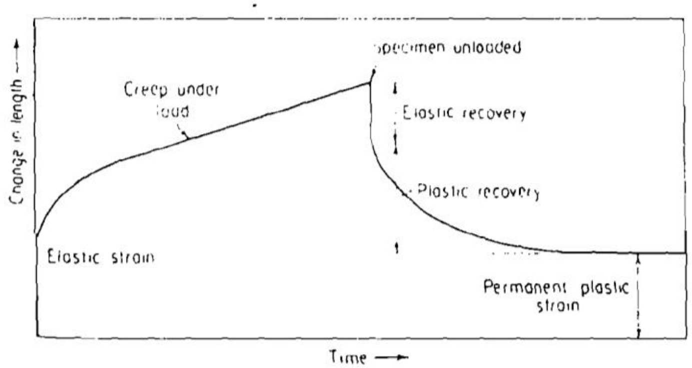


Figure 15.3 Recovery of strain after unloading.

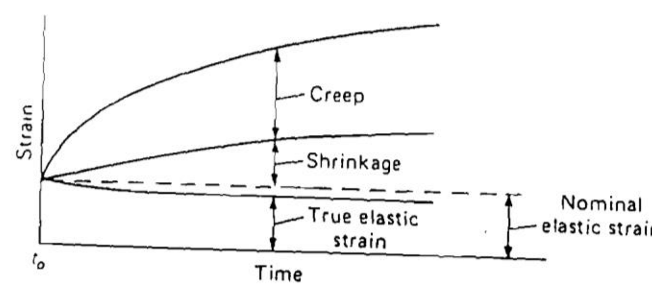


Figure 1.10.1 Change in strain of a loaded and drying specimen; t_0 is the time of application of load. (Concrete)

Creep Test Data Sheet

Type of Alloy: Original Diameter Weight (g)

Name	Date	Time	Temp (C)	Distance Between Marks

Table 6-6 Data from a Creep Test		
Time (h)	Strain (in/in)	
0	0.003	
250	0.006	
1000	0.009	
2250	0.012	
3500	0.015	
4750	0.018	
6000	0.021	
7100	0.024	
7500	0.027	
7750	0.030	fracture

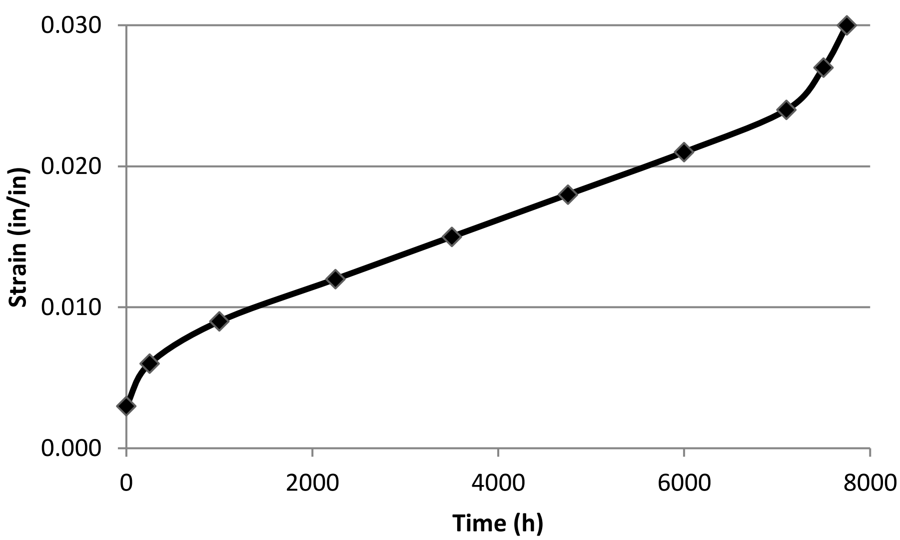


Figure 6-6

Experiment Two: Tension Test

Reference: Chapter 8 pp. 25-150 of GE207 text by Davis, Troxell & Hauck
Chapter 2 pp. 39-49 of GE206 textbook by Beer & Johnston

INTRODUCTION

The tension test is one of the basic methods used in evaluating the fundamental mechanical properties of a material to be used in design. To effectively design an engineering member to perform a specified purpose, it is necessary that the properties which characterize reaction of the material from which the member is made are obtained from stress-strain diagrams which are compiled from the resultant data of the standard tension test performed on the material.

In this experiment, the student will perform a tension test on three different materials. From the tension test results, the strength and several elastic and non-elastic properties of the materials will be determined. Also, from the result, the material behavior during failure can be evaluated; ductile, brittle, and tough failure.

LABORATORY PROCEDURE

In this experiment, the student will perform a tension test on three different materials: Carbon steel, Aluminum and Plastic. A specimen of each material will be loaded in the Tinius Olsen Tester. Load and corresponding deformation will be automatically generated and recorded in the Tinius Olsen machine for each sample tested.

- Steel – continuously
- Aluminum – continuously
- Plastic – continuously

The extensometer can be attached to the specimen to measure the elongation of the specimen. It is important to note to select the correct program in the Tinius Olsen Machine so it will pause the test to remove the extensometer. Not removing the device may damage it.

Stress versus strain relationship will be plotted from these data to obtain additional information required for the evaluation of this experiment. The Tinius Olsen Machine will plot force versus position. It will also output 1,000 data points to be used in calculations to give a good comparison against the reference values for the following:

- Modulus of Elasticity, E (psi)
- Elastic Limit
- Yield Strength
- Ultimate Strength

For each specimen, record the initial length and cross-sectional area. The length should be measured between the base of the flanges on the center of the specimen. Take necessary photos of the specimens after failure to also include in your report. Compare the empirical values that were calculated, and the references values mentioned above for accuracy. Calculate offset for yield strength (%) for each material. Ensure the results make sense and comment on any possible sources of error.

Experiment Three: Compression Test on Wood

Reference: Chapter 9 "Static Compression" and Chapter 20 "Wood".

Introduction:

Wood is a non-metal of biological origin, often used in structures. The cross section of wood is not homogeneous, contains defects, such as checks, cracks, knots, warp, decay, shakes, and so on. The material properties of wood vary a great deal more than those of metals. Because of the variation in materials properties as well as lack of understanding, wood is often misused, or used to less than its full capacity. In this lab, you will test several samples of typical "hard" wood and a typical "soft" wood. The numbers of specimens and species of wood will vary from one semester to another. The instructor will provide information on the specimens used.

Instructions

1. Measure and record the original lengths and cross-sectional dimensions of each specimen.
2. Place the specimen in the Tinius Olsen Testing Machine and attach instrumentation as instructed.
3. Apply a gradually increasing axial compression load to the sample continuously to failure.
4. The loads and the corresponding deformation readings are automatically generated and recorded in the Tinius Olsen Machine.

Instructions on how to properly use the Tinius Olsen Machine are located in the appendix.

Note: If the specimen shatters abruptly, the test is clearly over. If the specimen develops a shear failure on an angular plane, stop before destroying the specimen. Sketch the specimen in the failed condition.

Evaluations

1. Graphs- Plot a Stress-Strain Diagram for each Test
2. Computations for all specimens

- Properties: Using your graphs determine if possible
  a. Modulus of Elasticity
  b. Yield point or Yield Strength (Based on 0.1% Offset)
  c. Ultimate Strength (if the specimen actually broke)
- Also compare the values with corresponding values from a reference text. If any value cannot be determined from your test enter "not determined."

The appendix contains the necessary information for various wood types.

Note

Do your values for the properties make sense? For example, if your value of E for wood is $4*10^6$ PSI, something must be wrong. You may not be able to find the error, but you must be able to recognize whether your experimental values are "in the correct ballpark" or not. Comment as necessary.

Comparison of Behavior in Tension and Compression

For each of the materials tested and for each of the following properties:

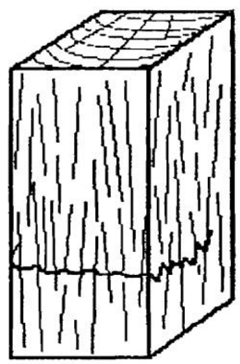
1. Modulus of Elasticity
2. Yield point or Yield Strength
3. Ultimate Strength

Would you expect compressive tests values to be higher than, lower than or equal to the tensile values? Consult your text, as we did not verify all these items in our testing program.

A16

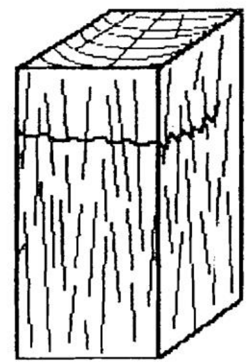
SKETCH OF SPECIMEN FAILURES

Birch



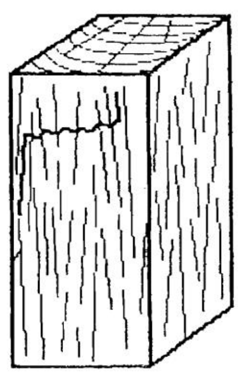
Failure approximately horizontal
Characteristic: Crushing

Douglas Fir



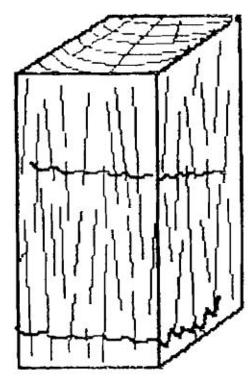
Failure approximately horizontal
Characteristic: Crushing

Hemlock



Failure at angle to horizontal
Characteristic: Shearing & Splitting

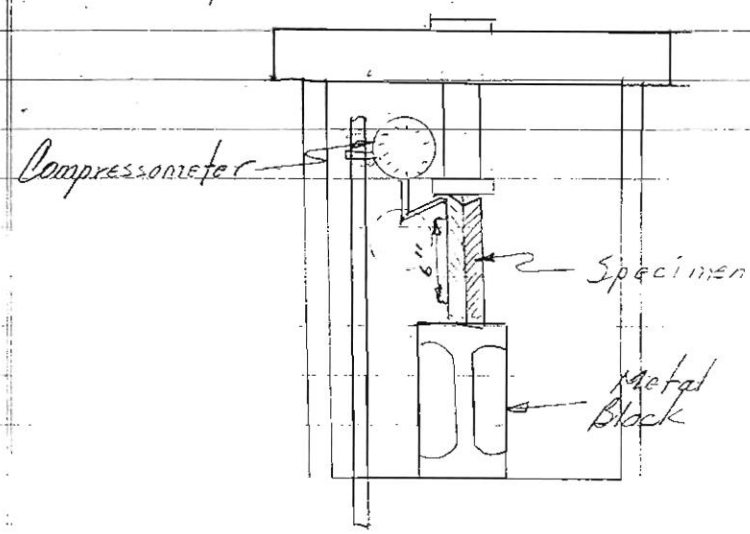
Oak



Failure approximately horizontal
Characteristic: Crushing

page 159 - Ch. 9 - types of failure
Chapter 20, p. 394 - properties of wood.

Use the compressometer that clamps on the wood specimen



Load and record in 500 pound increments until failure

growth rings
early wood - spring - light
late wood - dark - dry

Shear - 159
Property 395 - 405
Hardwood - deciduous - Broadleaf
Soft Wood - Coniferous - cone bearing, evergreen

Experiment Four: Shear Force in Beams

Reference: TQ Student guide (Next five pages)

List of Tasks:

1. Perform Experiment 1 “Shear Force Variation with Increasing Load” as directed in the Student Guide.
2. Perform Experiment 2 “Shear Force Variation with Various Load Conditions” as directed in the Student Guide.
    a. In the case of Experiment 2 part a, repeat for the 0.98N, 1.96N, 2.94N and 4.9N loads.
3. Develop a diagram representing the variation in the shear force measured at the cut, C, as a fixed unit load moves from one end of the beam to the other. Do this by plotting the magnitude of the shear force as ordinate at the point of application along the beam. Use this diagram to estimate the magnitude of the shear force at C from a 10N load 180mm to the right of the support A. Discuss your results.

SECTION 1 INTRODUCTION AND DESCRIPTION

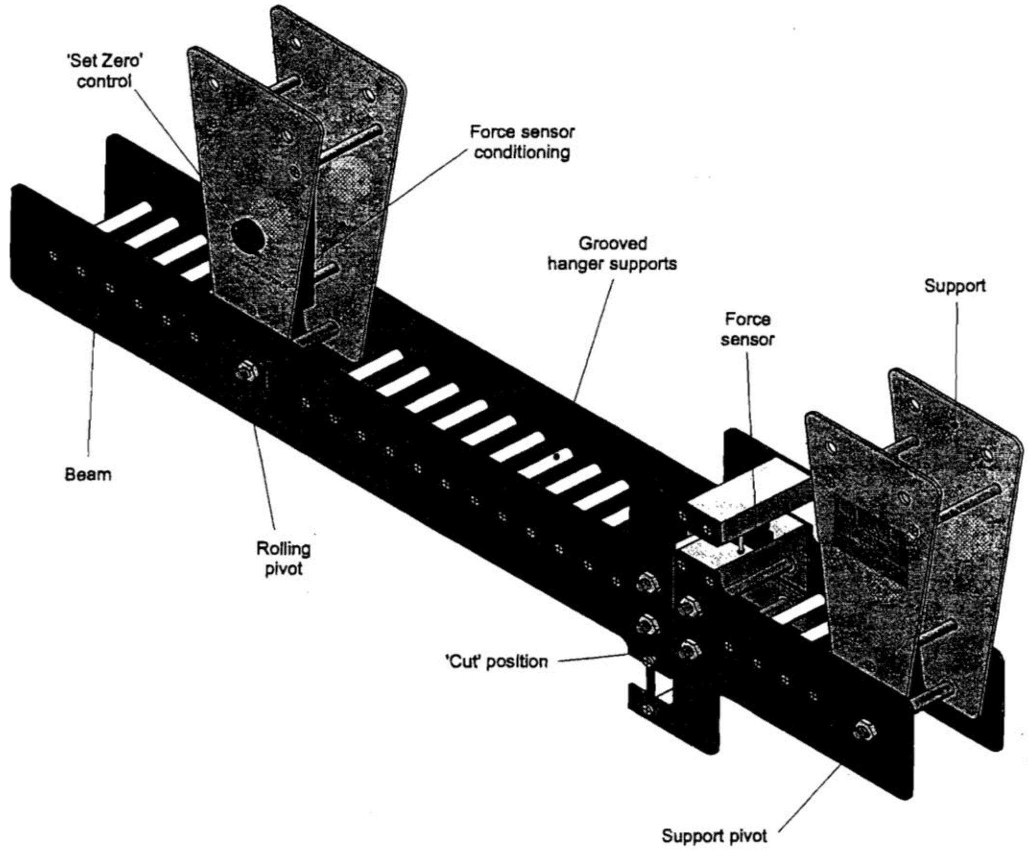


Figure 1 Shear forces in a beam experiment

Introduction

This guide describes how to set up and perform Shear Force in a Beam experiments. It clearly demonstrates the principles involved and gives practical support to your studies.

Description

Figure 1 shows the Shear Force in a Beam experiment. It consists of a beam which is 'cut'. To stop the beam collapsing a mechanism, (which allows movement in the shear direction only) bridges the cut on to a load cell thus reacting (and measuring) the shear force. A digital display shows the force from the load cell.

A diagram on the left-hand support of the beam shows the beam geometry and hanger positions. Hanger supports are 20 mm apart, and have a central groove which positions the hangers.

How to Set Up the Equipment

The Shear Force in a Beam experiment fits into a Test Frame. Figure 2 shows the Shear Force of a Beam experiment assembled in the Frame.

Before setting up and using the equipment, **always:**

- Visually inspect all parts, including electrical leads, for damage or wear.
- Check electrical connections are correct and secure.
- Check all components are secured correctly and fastenings are sufficiently tight.
- Position the Test Frame safely. Make sure it is mounted on a solid, level surface, is steady, and easily accessible.

Never apply excessive loads to any part of the equipment.

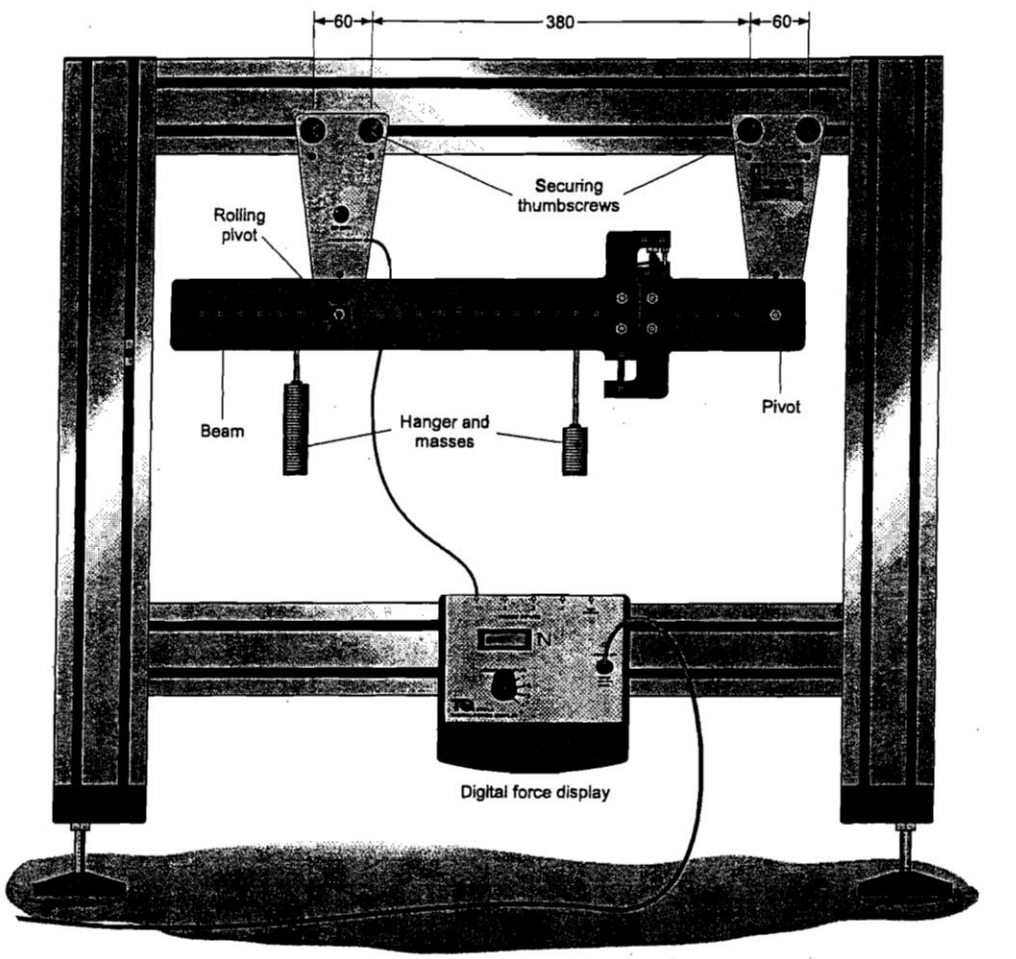


Figure 2 Shear force of a beam experiment in the structures frame

Steps 1 to 4 of the following instructions may already have been completed for you.

1. Place an assembled Test Frame (refer to the separate instructions supplied with the Test Frame if necessary) on a workbench. Make sure the 'window' of the Test Frame is easily accessible.
2. There are four securing nuts in the top member of the frame. Slide them to approximately the positions shown in Figure 3.
3. With the right-hand end of the experiment resting on the bottom member of the Test Frame, fit the left-hand support to the top member of the frame. Push the support on to the frame to ensure that the internal bars are sitting on the frame squarely. Tighten the support in position by screwing two of the thumbscrews provided into the securing nuts (on the front of the support only).
4. Lift the right-hand support into position and locate the two remaining thumbscrews into the securing nuts. Push the support on to the frame to ensure the internal bars are sitting on the frame squarely. Position the support horizontally so the rolling pivot is in the middle of its travel. Tighten the thumbscrews.
5. Make sure the Digital Force Display is 'on'. Connect the mini DIN lead from 'Force Input 1' on the Digital Force Display to the socket marked 'Force Output' on the left-hand support of the experiment. Ensure the lead does not touch the beam.
6. Carefully zero the force meter using the dial on the left-hand beam of the experiment. Gently apply a small load with a finger to the centre of the beam and release. Zero the meter again if necessary. Repeat to ensure the meter returns to zero.

Note: If the meter is only ±0.1 N, lightly tap the frame (there may be a little 'stiction' and this should overcome it).

SECTION 2 EXPERIMENTS

Experiment 1: Shear Force Variation with an Increasing Point Load

This experiment examines how shear force varies with an increasing point load. Figure 3 shows the force diagram for the beam.

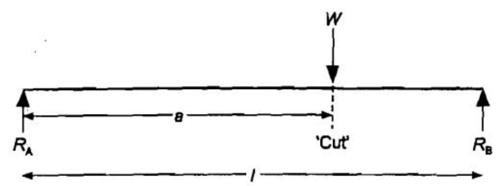


Figure 3 Force diagram

The equation we will use in this experiment is:

$$\text{Shear force at cut, } S_c = \frac{W.a}{l}$$

You may find the following table useful in converting the masses used in the experiments to loads.

Mass (Grams)	Load (Newtons)
100	0.98
200	1.96
300	2.94
400	3.92
500	4.90

Table 1 Grams to Newtons conversion table

Check the Digital Force Display meter reads zero with no load.

Place a hanger with a 100 g mass to the left of the 'cut'. Record the Digital Force Display reading in a table as in Table 2. Repeat using masses of 200 g, 300 g, 400 g and 500 g. Convert the mass into a load (in N).

Remember,

Shear force at the cut = Displayed force

Calculate the theoretical shear force at the cut and complete the table.

Mass (g)	Load (N)	Experimental shear force (N)	Theoretical shear force (N)
0			
100			
200			
300			
400			
500			

Table 2 Results for Experiment 1

Plot a graph which compares your experimental results to those you calculated using the theory.

Comment on the shape of the graph. What does it tell us about how shear force varies due to an increased load? Does the equation we used accurately predict the behaviour of the beam?

Experiment 2: Shear Force Variation for Various Loading Conditions

This experiment examines how shear force varies at the cut position of the beam for various loading conditions. Figure 4, Figure 5 and Figure 6 show the force diagrams.

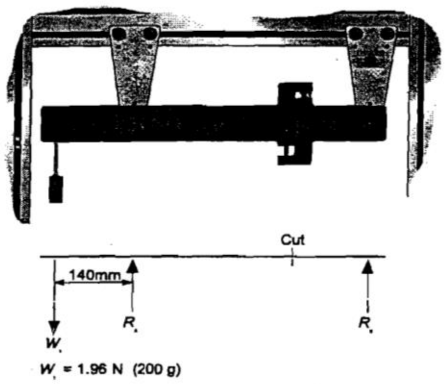


Figure 4 Force diagram

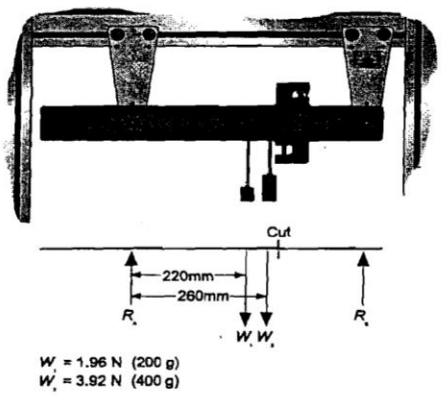


Figure 5 Force diagram

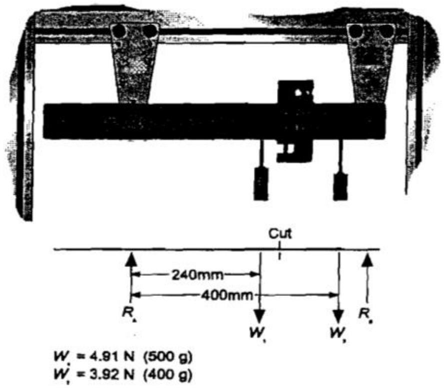


Figure 6 Force diagram

We will use the statement:

"The Shear force at the 'cut' is equal to the algebraic sum of the forces acting to the left or right of the cut."

Check the Digital Force Display meter reads zero with no load.

Carefully load the beam with the hangers in the positions shown in Figure 4, using the loads indicated in Table 2.

Record the Digital Force Display reading as in Table 3. Remember,

Shear force at the cut (N) = Displayed force

Calculate the support reactions (R_A and R_B) and calculate the theoretical shear force at the cut.

Repeat the procedure with the beam loaded as in Figure 5 and Figure 6.

Comment on how the results of the experiments compare with those calculated using the theory.

Figure	W_1 (N)	W_2 (N)	Force (N)	Experimental shear force (N)	R_A (N)	R_B (N)	Theoretical shear force (Nm)
4	3.92						
5	1.96	3.92					
6	4.91	3.92					

Table 2 Results for Experiment 2

Experiment Five: Torsion of Circular Sections

Reference: TQ STR6 Torsion of Circular Sections: Student guide (Next six pages)

Troubleshooting

In experiment 3, there may be some issues attempting to get the brass tube to 4 or 5 N since the angle adjustment may max out. In order to solve this issue, rotate the thumbscrew until it no longer makes contact with the angle readout. Raise the pointer arm until it is all the way up. Rotate the thumbwheel until the force readout reads 0.3 N. Reposition the pointer arm to 0-degree readout. Then continue the experiment like normal. The idea is to give the maximum possible distance to change the angle.

Experiment 1: Torsional Deflection of a Solid Rod

This experiment examines the relationship between torque and angular deflection of a solid circular section. Further work will show how the properties of the material affect this relationship.

With a pencil and a rule, mark the steel and brass rods with these distances from the left-hand end (note that the rubber tip is on the right-hand end):

- 15 mm,
- 315 mm,
- 365 mm,
- 415 mm,
- 465 mm,
- 515 mm.

Wind the thumbwheel down to its stop. Position the steel rod from the right-hand side with the rubber tipped end sticking out. Line up the first mark with the left-hand chuck (note the jaws of the chuck move outward as they close!). Tighten it fully using the chuck key in the three holes.

Undo the four thumbnuts which stop the chuck from sliding. Slide the chuck until the last mark (515 mm) lines up with the right-hand chuck. This procedure sets the rod length at 500 mm. Fully tighten the right-hand chuck using the chuck key in each of the three holes.

Wind the thumbwheel until the force meter reads 0.3 N to 0.5 N. Zero the force meter and the angle scale using the moveable pointer arm. Wind the thumbwheel so the force meter reads 5 N and then back to zero. If the angle reading is not zero check the tightness of the chucks and start again.

Take readings of the angle every 1 N of force: you should take the reading just as the reading changes. Take readings to a maximum of 5 N of force. Enter all the readings into Table 2. To convert the load cell readings to torque multiply by the torque arm length (0.05 m).

Repeat the set up and procedure for the brass rod and enter your results in Table 3.

Force (N)	Torque, T (Nm)	Angular deflection (°)
0	0	0
1		
2		
3		
4		
5		

Table 2 Results for steel rod

Force (N)	Torque, T (Nm)	Angular deflection (°)
0	0	0
1		
2		
3		
4		
5		

Table 3 Results for a brass rod

From your results, on the same graph plot torque versus angle for both rods

Comment on the shape of the graph. What does it tell us about how angle of deflection varies because of an increased torque? Name at least three applications or situations where torsional deflection would undesirable and one application where it could be desirable or of use.

Take a look at the formulas on the backboard that predicts the behaviour of the rods. What would happen to the relative stiffness of the rod if the diameter were increased from 3 mm to 4 mm?

Further Work

Measure the diameter of both the rods with the vernier as accurately as you can (remember the affect of a small error in the diameter!). Calculate J values for each rod using the formulae on the backboard of the equipment.

Fill in Tables 4 and 5 from your experimental results to establish values of TL and $J\theta$. Remember you must convert your angle measurements from degrees to radians (2π radians = 360°).

Diameter of steel section, *d*	________ mm
Polar moment of inertia, *J*	________ $\times 10^{-12}$ m^4
Length *L*	0.5 m

Torque (Nm)	Angular deflection, θ (rad)	*TL*	$J\theta \times 10^{-13}$
0			
0.05			
0.10			
0.15			
0.20			
0.25			

Table 4 Calculated values for a steel rod

Diameter of brass section, *d*	________ mm
Polar moment of inertia, *J*	________ $\times 10^{-12}$ m^4
Length *L*	0.5 m

Torque (Nm)	Angular deflection, θ (rad)	*TL*	$J\theta \times 10^{-13}$
0			
0.05			
0.10			
0.15			
0.20			
0.25			

Table 5 Calculated values for a brass rod

Plot a graph of TL against $J\theta$. Examine the torsion formula and say what the value of the gradient represents. Does the value compare favourably with typical ones?

Experiment 2: The Effect of Rod Length on Torsional Deflection

This experiment examines the relationship between torsional deflection and rod length at a constant torque.

If you have completed Experiment 1 you will have already completed some of the following steps. In which case you can leave the brass rod in place at 500 mm long.

With a pencil and a rule, mark the steel and brass rods these distances from the left-hand end (note that the rubber tip is on the right-hand end):

- 15 mm,
- 315 mm,
- 365 mm,
- 415 mm,
- 465 mm,
- 515 mm.

Wind the thumbwheel down to its stop. Position the steel rod from the right-hand side with the rubber tipped end sticking out. Line up the first mark with the left-hand chuck (note the jaws of the chuck move outward as they close!). Tighten it fully using the chuck key in each of the three holes.

Undo the four thumbnuts which stop the chuck from sliding. Slide the chuck until the last mark (515 mm) lines up with the right-hand chuck. This procedure sets the rod length at 500 mm. Fully tighten the right-hand chuck using the chuck key in each of the three holes.

Wind the thumbwheel until the force meter reads 0.3 N to 0.5 N. Zero the force meter and the angle scale using the moveable pointer arm. Wind the thumbwheel so the force meter reads 5 N and then back to zero. If the angle reading is not zero check the tightness of the chucks and start again.

Wind the thumbwheel so the torque is 0.15 Nm (a reading of 3 N) and note down the angle in Table 6. Reduce the length of the rod to the next mark (450 mm) and reset. Take a reading of angle at the same torque and record. Repeat this procedure for lengths down to 300 mm.

Dia. of brass rod	_____ mm	Torque, T	0.15 Nm

Length (m)	Angular deflection (°)
0.30	
0.35	
0.40	
0.45	
0.50	

Table 6 Results for a brass rod

Plot a graph of angular deflection against rod length. Comment on the shape of the plot.

On most front-wheel drive vehicles have unequal length drive shafts (from side-to-side). This is because of the gearbox position being at one end of the engine. This mismatch in length causes an undesirable effect on the steering as the car accelerates (that is, as torque from the engine increases). Why is that? What could eliminate the effect?

Experiment 3: Comparison of Solid Rod and Tube

This experiment compares the torsional deflection of a solid rod and a tube with a similar diameters.

With a pencil and a rule mark the brass tube and brass rods at 15 mm and 515 mm from the left-hand end (the end without the rubber tip).

Wind the angle thumbwheel down to its stop. Position the brass tube in from the right-hand side with the rubber tip end sticking out. Line up the first mark with the left-hand chuck (note the jaws of the chuck move outward as they close!). Tighten it fully using the chuck key in each of the three holes.

Undo the four thumbnuts that stop the chuck from sliding. Slide the chuck until the last mark (515 mm) lines up with the right-hand chuck. This sets the rod length at 500 mm. Fully tighten the right-hand chuck using the chuck key in each of the three holes.

Wind the thumbwheel until the force meter reads 0.3 N to 0.5 N. Zero the force meter and the angle scale with the moveable pointer arm. Wind the thumbwheel so the force meter reads 5 N and then back to zero. If the angle reading is not zero check the tightness of the chucks and start again.

Take readings of the angle every 1 N of force: you should take the reading just as the reading changes. Take readings to a maximum of 5 N of force. Enter all the readings into Table 7. To convert the load cell readings to torque multiply by the torque arm length (0.05 m).

If you have completed Experiment 1, enter your results for the solid brass rod in Table 7. If not, repeat the set up and procedure for the solid brass rod.

Force (N)	Torque (Nm)	Rod angular deflection (°)	Tube angular deflection (°)
0			
1			
2			
3			
4			
5			

Table 7 Results for brass rod and tube

Calculate the J values for the solid rod and tube. To calculate J for a tube, find J for a solid of the same diameter then subtract J for the missing material in the centre. Examine your results and the J values you have calculated and comment on the effect of the missing material.

Assuming a density of $8450\,\mathrm{kgm^{-3}}$ for brass, work out the nominal mass per unit length of both the tube and the solid rod. Comment on the efficiency of designing torsional members out of tube instead of solid material.

Experiment Six: Charpy Impact Test/Ductile to Brittle Transitional Temperature Test

Introduction

In this lab we will be using the Charpy Impact Test to investigate two phenomena:

1. The influence of carbon content and strain hardening on the impact strength of plain carbon steel.
2. The influence of temperature on the impact strength of steel and the influence of a sharply defined ductile to brittle transition temperature for some ferrous metals.

Laboratory Procedure

In this lab, 3 different materials will be tested at 4 various temperatures. The materials selected will be up to the instructor. One of each specimen will be tested at 4 different temperatures after being placed in dry ice, boiling water, ice water, and left at room temperature. Since the sample pieces are quite small, they should change temperature moderately quickly to match the medium it is placed in. However, this also means that it will try to approach room temperature moderately fast, so you must work quickly and carefully. When handling the specimens, wear gloves and use tongs.

Each of the specimens have a notch cut out in the test piece. When placing the test piece in the Charpy Test, ensure you place the notch facing away from the point of impact from the swinging pendulum.

Place 1 specimen from each material in the boiling water, dry ice, and ice water. Leave the last specimen on the counter. Bring water to a rolling boil in a container and keep it boiling. Place a temperature probe in the boiling water and the ice water to measure the temperature of the water. Record the temperature of the room as the temperature for the room temperature specimens. For this lab, it is extremely difficult to accurately measure the specimen temperatures since they are small. We will assume the temperature of the medium is the temperature of the specimen. Keep in mind this is not entirely accurate since the temperatures will change when removing the specimens from the medium over to the test. That is why you must move quickly. The average temperature for dry ice is -109° F. Before testing, ensure you have 3 different specimens in each medium, producing 12 different tests, that have been allowed enough time to come to the temperature of the medium it is in, or close to it.

When testing, remove the specimen from the medium with the tongs, and place on the ledge in the Charpy test with the notch facing away from the impact spot as centered as possible. Remember to move quickly. Raise the pendulum all the way to the top, to lock it in place. Have someone keep a hand close enough to the pendulum to catch it in case it does not latch, and it falls and hurts the person attempting to place the test. Set the dial indicator to 15 J. Ensure everyone is clear and drop the pendulum. Collect the pieces of the specimen and record the fracture area and the impact energy readout. Calculate the impact strength (KCU). Make notes on how the specimen fractured, if it did. Do this for all 12 tests. In your report, mention possible sources of error for this experiment.

Table 1 Charpy test data

Temperature Stage	Material	Temperature (°F)	Impact Energy (J)	Fracture Area (cm^2)	Impact Strength (KCU)
Dry Ice		-109			
		-109			
		-109			
Ice Water					
Room Temperature					
Boiling Water					

References

[1] Forest Products Laboratory. 1999. Wood handbook—Wood as an engineering material. Gen. Tech. Rep. FPL–GTR–113. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 463 p.

Appendix

Wood Tables [1]

Table 4–3b. Strength properties of some commercially important woods grown in the United States (inch–pound)[a]

Common species names	Moisture content	Specific gravity[b]	Static bending			Impact bending (in.)	Compression parallel to grain (lbf/in²)	Compression perpendicular to grain (lbf/in²)	Shear parallel to grain (lbf/in²)	Tension perpendicular to grain (lbf/in²)	Side hardness (lbf)
			Modulus of rupture (lbf/in²)	Modulus of elasticity[c] (×10⁶ lbf/in²)	Work to maximum load (in-lbf/in³)						
Hardwoods											
Alder, red	Green	0.37	6,500	1.17	8.0	22	2,960	250	770	390	440
	12%	0.41	9,800	1.38	8.4	20	5,820	440	1,080	420	590
Ash											
Black	Green	0.45	6,000	1.04	12.1	33	2,300	350	860	490	520
	12%	0.49	12,600	1.60	14.9	35	5,970	760	1,570	700	850
Blue	Green	0.53	9,600	1.24	14.7	—	4,180	810	1,540	—	—
	12%	0.58	13,800	1.40	14.4	—	6,980	1,420	2,030	—	—
Green	Green	0.53	9,500	1.40	11.8	35	4,200	730	1,260	590	870
	12%	0.56	14,100	1.66	13.4	32	7,080	1,310	1,910	700	1,200
Oregon	Green	0.50	7,600	1.13	12.2	39	3,510	530	1,190	590	790
	12%	0.55	12,700	1.36	14.4	33	6,040	1,250	1,790	720	1,160
White	Green	0.55	9,500	1.44	15.7	38	3,990	670	1,350	590	960
	12%	0.60	15,000	1.74	16.6	43	7,410	1,160	1,910	940	1,320
Aspen											
Bigtooth	Green	0.36	5,400	1.12	5.7	—	2,500	210	730	—	—
	12%	0.39	9,100	1.43	7.7	—	5,300	450	1,080	—	—
Quaking	Green	0.35	5,100	0.86	6.4	22	2,140	180	660	230	300
	12%	0.38	8,400	1.18	7.6	21	4,250	370	850	260	350
Basswood, American	Green	0.32	5,000	1.04	5.3	16	2,220	170	600	280	250
	12%	0.37	8,700	1.46	7.2	16	4,730	370	990	350	410
Beech, American	Green	0.56	8,600	1.38	11.9	43	3,550	540	1,290	720	850
	12%	0.64	14,900	1.72	15.1	41	7,300	1,010	2,010	1,010	1,300
Birch											
Paper	Green	0.48	6,400	1.17	16.2	49	2,360	270	840	380	560
	12%	0.55	12,300	1.59	16.0	34	5,690	600	1,210	—	910
Sweet	Green	0.60	9,400	1.65	15.7	48	3,740	470	1,240	430	970
	12%	0.65	16,900	2.17	18.0	47	8,540	1,080	2,240	950	1,470
Yellow	Green	0.55	8,300	1.50	16.1	48	3,380	430	1,110	430	780
	12%	0.62	16,600	2.01	20.8	55	8,170	970	1,880	920	1,260
Butternut	Green	0.36	5,400	0.97	8.2	24	2,420	220	760	430	390
	12%	0.38	8,100	1.18	8.2	24	5,110	460	1,170	440	490
Cherry, black	Green	0.47	8,000	1.31	12.8	33	3,540	360	1,130	570	660
	12%	0.50	12,300	1.49	11.4	29	7,110	690	1,700	560	950
Chestnut, American	Green	0.40	5,600	0.93	7.0	24	2,470	310	800	440	420
	12%	0.43	8,600	1.23	6.5	19	5,320	620	1,080	460	540
Cottonwood											
Balsam, poplar	Green	0.31	3,900	0.75	4.2	—	1,690	140	500	—	—
	12%	0.34	6,800	1.10	5.0	—	4,020	300	790	—	—
Black	Green	0.31	4,900	1.08	5.0	20	2,200	160	610	270	250
	12%	0.35	8,500	1.27	6.7	22	4,500	300	1,040	330	350
Eastern	Green	0.37	5,300	1.01	7.3	21	2,280	200	680	410	340
	12%	0.40	8,500	1.37	7.4	20	4,910	380	930	580	430
Elm											
American	Green	0.46	7,200	1.11	11.8	38	2,910	360	1,000	590	620
	12%	0.50	11,800	1.34	13.0	39	5,520	690	1,510	660	830
Rock	Green	0.57	9,500	1.19	19.8	54	3,780	610	1,270	—	940
	12%	0.63	14,800	1.54	19.2	56	7,050	1,230	1,920	—	1,320
Slippery	Green	0.48	8,000	1.23	15.4	47	3,320	420	1,110	640	660
	12%	0.53	13,000	1.49	16.9	45	6,360	820	1,630	530	860
Hackberry	Green	0.49	6,500	0.95	14.5	48	2,650	400	1,070	630	700
	12%	0.53	11,000	1.19	12.8	43	5,440	890	1,590	580	880

Table 4–3b. Strength properties of some commercially important woods grown in the United States (inch–pound)[a]—con.

Common species names	Moisture content	Specific gravity[b]	Static bending: Modulus of rupture (lbf/in²)	Static bending: Modulus of elasticity[c] ($\times 10^6$ lbf/in²)	Static bending: Work to maximum load (in-lbf/in³)	Impact bending (in.)	Compression parallel to grain (lbf/in²)	Compression perpendicular to grain (lbf/in²)	Shear parallel to grain (lbf/in²)	Tension perpendicular to grain (lbf/in²)	Side hardness (lbf)
Hickory, pecan											
Bitternut	Green	0.60	10,300	1.40	20.0	66	4,570	800	1,240	—	—
	12%	0.66	17,100	1.79	18.2	66	9,040	1,680	—	—	—
Nutmeg	Green	0.56	9,100	1.29	22.8	54	3,980	760	1,030	—	—
	12%	0.60	16,600	1.70	25.1	—	6,910	1,570	—	—	—
Pecan	Green	0.60	9,800	1.37	14.6	53	3,990	780	1,480	680	1,310
	12%	0.66	13,700	1.73	13.8	44	7,850	1,720	2,080	—	1,820
Water	Green	0.61	10,700	1.56	18.8	56	4,660	880	1,440	—	—
	12%	0.62	17,800	2.02	19.3	53	8,600	1,550	—	—	—
Hickory, true											
Mockernut	Green	0.64	11,100	1.57	26.1	88	4,480	810	1,280	—	—
	12%	0.72	19,200	2.22	22.6	77	8,940	1,730	1,740	—	—
Pignut	Green	0.66	11,700	1.65	31.7	89	4,810	920	1,370	—	—
	12%	0.75	20,100	2.26	30.4	74	9,190	1,980	2,150	—	—
Shagbark	Green	0.64	11,000	1.57	23.7	74	4,580	840	1,520	—	—
	12%	0.72	20,200	2.16	25.8	67	9,210	1,760	2,430	—	—
Shellbark	Green	0.62	10,500	1.34	29.9	104	3,920	810	1,190	—	—
	12%	0.69	18,100	1.89	23.6	88	8,000	1,800	2,110	—	—
Honeylocust	Green	0.60	10,200	1.29	12.6	47	4,420	1,150	1,660	930	1,390
	12%	—	14,700	1.63	13.3	47	7,500	1,840	2,250	900	1,580
Locust, black	Green	0.66	13,800	1.85	15.4	44	6,800	1,160	1,760	770	1,570
	12%	0.69	19,400	2.05	18.4	57	10,180	1,830	2,480	640	1,700
Magnolia											
Cucumbertree	Green	0.44	7,400	1.56	10.0	30	3,140	330	990	440	520
	12%	0.48	12,300	1.82	12.2	35	6,310	570	1,340	660	700
Southern	Green	0.46	6,800	1.11	15.4	54	2,700	460	1,040	610	740
	12%	0.50	11,200	1.40	12.8	29	5,460	860	1,530	740	1,020
Maple											
Bigleaf	Green	0.44	7,400	1.10	8.7	23	3,240	450	1,110	600	620
	12%	0.48	10,700	1.45	7.8	28	5,950	750	1,730	540	850
Black	Green	0.52	7,900	1.33	12.8	48	3,270	600	1,130	720	840
	12%	0.57	13,300	1.62	12.5	40	6,680	1,020	1,820	670	1,180
Red	Green	0.49	7,700	1.39	11.4	32	3,280	400	1,150	—	700
	12%	0.54	13,400	1.64	12.5	32	6,540	1,000	1,850	—	950
Silver	Green	0.44	5,800	0.94	11.0	29	2,490	370	1,050	560	590
	12%	0.47	8,900	1.14	8.3	25	5,220	740	1,480	500	700
Sugar	Green	0.56	9,400	1.55	13.3	40	4,020	640	1,460	—	970
	12%	0.63	15,800	1.83	16.5	39	7,830	1,470	2,330	—	1,450
Oak, red											
Black	Green	0.56	8,200	1.18	12.2	40	3,470	710	1,220	—	1,060
	12%	0.61	13,900	1.64	13.7	41	6,520	930	1,910	—	1,210
Cherrybark	Green	0.61	10,800	1.79	14.7	54	4,620	760	1,320	800	1,240
	12%	0.68	18,100	2.28	18.3	49	8,740	1,250	2,000	840	1,480
Laurel	Green	0.56	7900	1.39	11.2	39	3,170	570	1,180	770	1,000
	12%	0.63	12,600	1.69	11.8	39	6,980	1,060	1,830	790	1,210
Northern red	Green	0.56	8300	1.35	13.2	44	3,440	610	1,210	750	1,000
	12%	0.63	14,300	1.82	14.5	43	6,760	1,010	1,780	800	1,290
Pin	Green	0.58	8300	1.32	14.0	48	3,680	720	1,290	800	1,070
	12%	0.63	14000	1.73	14.8	45	6,820	1,020	2,080	1,050	1,510
Scarlet	Green	0.60	10,400	1.48	15.0	54	4,090	830	1,410	700	1,200
	12%	0.67	17400	1.91	20.5	53	8,330	1,120	1,890	870	1,400
Southern red	Green	0.52	6,900	1.14	8.0	29	3,030	550	930	480	860
	12%	0.59	10,900	1.49	9.4	26	6,090	870	1,390	510	1,060

Table 4–3b. Strength properties of some commercially important woods grown in the United States (inch–pound)[a]—con.

Common species names	Moisture content	Specific gravity[b]	Static bending: Modulus of rupture (lbf/in²)	Static bending: Modulus of elasticity[c] (×10⁶ lbf/in²)	Static bending: Work to maximum load (in-lbf/in³)	Impact bending (in.)	Compression parallel to grain (lbf/in²)	Compression perpendicular to grain (lbf/in²)	Shear parallel to grain (lbf/in²)	Tension perpendicular to grain (lbf/in²)	Side hardness (lbf)
Oak, red—con.											
Water	Green	0.56	8,900	1.55	11.1	39	3,740	620	1,240	820	1,010
	12%	0.63	15,400	2.02	21.5	44	6,770	1,020	2,020	920	1,190
Willow	Green	0.56	7400	1.29	8.8	35	3,000	610	1,180	760	980
	12%	0.69	14,500	1.90	14.6	42	7,040	1,130	1,650	—	1,460
Oak, white											
Bur	Green	0.58	7,200	0.88	10.7	44	3,290	680	1,350	800	1,110
	12%	0.64	10,300	1.03	9.8	29	6,060	1,200	1,820	680	1,370
Chestnut	Green	0.57	8,000	1.37	9.4	35	3,520	530	1,210	690	890
	12%	0.66	13,300	1.59	11.0	40	6,830	840	1,490	—	1,130
Live	Green	0.80	11,900	1.58	12.3	—	5,430	2,040	2,210	—	—
	12%	0.88	18,400	1.98	18.9	—	8,900	2,840	2,660	—	—
Overcup	Green	0.57	8,000	1.15	12.6	44	3,370	540	1,320	730	960
	12%	0.63	12,600	1.42	15.7	38	6,200	810	2,000	940	1,190
Post	Green	0.60	8,100	1.09	11.0	44	3,480	860	1,280	790	1,130
	12%	0.67	13,200	1.51	13.2	46	6,600	1,430	1,840	780	1,360
Swamp chestnut	Green	0.60	8,500	1.35	12.8	45	3,540	570	1,260	670	1,110
	12%	0.67	13,900	1.77	12.0	41	7,270	1,110	1,990	690	1,240
Swamp white	Green	0.64	9,900	1.59	14.5	50	4,360	760	1,300	860	1,160
	12%	0.72	17,700	2.05	19.2	49	8,600	1,190	2,000	830	1,620
White	Green	0.60	8,300	1.25	11.6	42	3,560	670	1,250	770	1,060
	12%	0.68	15,200	1.78	14.8	37	7,440	1,070	2,000	800	1,360
Sassafras	Green	0.42	6,000	0.91	7.1	—	2,730	370	950	—	—
	12%	0.46	9,000	1.12	8.7	—	4,760	850	1,240	—	—
Sweetgum	Green	0.46	7,100	1.20	10.1	36	3,040	370	990	540	600
	12%	0.52	12,500	1.64	11.9	32	6,320	620	1,600	760	850
Sycamore, American	Green	0.46	6,500	1.06	7.5	26	2,920	360	1,000	630	610
	12%	0.49	10,000	1.42	8.5	26	5,380	700	1,470	720	770
Tanoak	Green	0.58	10,500	1.55	13.4	—	4,650	—	—	—	—
	12%	—	—	—	—	—	—	—	—	—	—
Tupelo											
Black	Green	0.46	7,000	1.03	8.0	30	3,040	480	1,100	570	640
	12%	0.50	9,600	1.20	6.2	22	5,520	930	1,340	500	810
Water	Green	0.46	7,300	1.05	8.3	30	3,370	480	1,190	600	710
	12%	0.50	9,600	1.26	6.9	23	5,920	870	1,590	700	880
Walnut, Black	Green	0.51	9,500	1.42	14.6	37	4,300	490	1,220	570	900
	12%	0.55	14,600	1.68	10.7	34	7,580	1,010	1,370	690	1,010
Willow, Black	Green	0.36	4,800	0.79	11.0	—	2,040	180	680	—	—
	12%	0.39	7,800	1.01	8.8	—	4,100	430	1,250	—	—
Yellow-poplar	Green	0.40	6,000	1.22	7.5	26	2,660	270	790	510	440
	12%	0.42	10,100	1.58	8.8	24	5,540	500	1,190	540	540
Softwoods											
Baldcypress	Green	0.42	6,600	1.18	6.6	25	3,580	400	810	300	390
	12%	0.46	10,600	1.44	8.2	24	6,360	730	1,000	270	510
Cedar											
Atlantic white	Green	0.31	4,700	0.75	5.9	18	2,390	240	690	180	290
	12%	0.32	6,800	0.93	4.1	13	4,700	410	800	220	350
Eastern redcedar	Green	0.44	7,000	0.65	15.0	35	3,570	700	1,010	330	650
	12%	0.47	8,800	0.88	8.3	22	6,020	920	—	—	—
Incense	Green	0.35	6,200	0.84	6.4	17	3,150	370	830	280	390
	12%	0.37	8,000	1.04	5.4	17	5,200	590	880	270	470
Northern White	Green	0.29	4,200	0.64	5.7	15	1,990	230	620	240	230
	12%	0.31	6,500	0.80	4.8	12	3,960	310	850	240	320

Table 4–3b. Strength properties of some commercially important woods grown in the United States (inch–pound)[a]—con.

Common species names	Moisture content	Specific gravity[b]	Static bending: Modulus of rupture (lbf/in²)	Static bending: Modulus of elasticity[c] (×10⁶ lbf/in²)	Static bending: Work to maximum load (in-lbf/in³)	Impact bending (in.)	Compression parallel to grain (lbf/in²)	Compression perpendicular to grain (lbf/in²)	Shear parallel to grain (lbf/in²)	Tension perpendicular to grain (lbf/in²)	Side hardness (lbf)
Cedar—con.											
Port-Orford	Green	0.39	6,600	1.30	7.4	21	3,140	300	840	180	380
	12%	0.43	12,700	1.70	9.1	28	6,250	720	1,370	400	630
Western redcedar	Green	0.31	5,200	0.94	5.0	17	2,770	240	770	230	260
	12%	0.32	7,500	1.11	5.8	17	4,560	460	990	220	350
Yellow	Green	0.42	6,400	1.14	9.2	27	3,050	350	840	330	440
	12%	0.44	11,100	1.42	10.4	29	6,310	620	1,130	360	580
Douglas-fir[d]											
Coast	Green	0.45	7,700	1.56	7.6	26	3,780	380	900	300	500
	12%	0.48	12,400	1.95	9.9	31	7,230	800	1,130	340	710
Interior West	Green	0.46	7,700	1.51	7.2	26	3,870	420	940	290	510
	12%	0.50	12,600	1.83	10.6	32	7,430	760	1,290	350	660
Interior North	Green	0.45	7,400	1.41	8.1	22	3,470	360	950	340	420
	12%	0.48	13,100	1.79	10.5	26	6,900	770	1,400	390	600
Interior South	Green	0.43	6,800	1.16	8.0	15	3,110	340	950	250	360
	12%	0.46	11,900	1.49	9.0	20	6,230	740	1,510	330	510
Fir											
Balsam	Green	0.33	5,500	1.25	4.7	16	2,630	190	662	180	290
	12%	0.35	9,200	1.45	5.1	20	5,280	404	944	180	400
California red	Green	0.36	5,800	1.17	6.4	21	2,760	330	770	380	360
	12%	0.38	10,500	1.50	8.9	24	5,460	610	1,040	390	500
Grand	Green	0.35	5,800	1.25	5.6	22	2,940	270	740	240	360
	12%	0.37	8,900	1.57	7.5	28	5,290	500	900	240	490
Noble	Green	0.37	6,200	1.38	6.0	19	3,010	270	800	230	290
	12%	0.39	10,700	1.72	8.8	23	6,100	520	1,050	220	410
Pacific silver	Green	0.40	6,400	1.42	6.0	21	3,140	220	750	240	310
	12%	0.43	11,000	1.76	9.3	24	6,410	450	1,220	—	430
Subalpine	Green	0.31	4,900	1.05	—	—	2,300	190	700	—	260
	12%	0.32	8,600	1.29	—	—	4,860	390	1,070	—	350
White	Green	0.37	5,900	1.16	5.6	22	2,900	280	760	300	340
	12%	0.39	9,800	1.50	7.2	20	5,800	530	1,100	300	480
Hemlock											
Eastern	Green	0.38	6,400	1.07	6.7	21	3,080	360	850	230	400
	12%	0.40	8,900	1.20	6.8	21	5,410	650	1,060	—	500
Mountain	Green	0.42	6,300	1.04	11.0	32	2,880	370	930	330	470
	12%	0.45	11,500	1.33	10.4	32	6,440	860	1,540	—	680
Western	Green	0.42	6,600	1.31	6.9	22	3,360	280	860	290	410
	12%	0.45	11,300	1.63	8.3	23	7,200	550	1,290	340	540
Larch, western	Green	0.48	7,700	1.46	10.3	29	3,760	400	870	330	510
	12%	0.52	13,000	1.87	12.6	35	7,620	930	1,360	430	830
Pine											
Eastern white	Green	0.34	4,900	0.99	5.2	17	2,440	220	680	250	290
	12%	0.35	8,600	1.24	6.8	18	4,800	440	900	310	380
Jack	Green	0.40	6,000	1.07	7.2	26	2,950	300	750	360	400
	12%	0.43	9,900	1.35	8.3	27	5,660	580	1,170	420	570
Loblolly	Green	0.47	7,300	1.40	8.2	30	3,510	390	860	260	450
	12%	0.51	12,800	1.79	10.4	30	7,130	790	1,390	470	690
Lodgepole	Green	0.38	5,500	1.08	5.6	20	2,610	250	680	220	330
	12%	0.41	9,400	1.34	6.8	20	5,370	610	880	290	480
Longleaf	Green	0.554	8,500	1.59	8.9	35	4,320	480	1,040	330	590
	12%	0.59	14,500	1.98	11.8	34	8,470	960	1,510	470	870
Pitch	Green	0.47	6,800	1.20	9.2	—	2,950	360	860	—	—
	12%	0.52	10,800	1.43	9.2	—	5,940	820	1,360	—	—

Table 4–3b. Strength properties of some commercially important woods grown in the United States (inch–pound)[a]—con.

Common species names	Moisture content	Specific gravity[b]	Static bending: Modulus of rupture (lbf/in²)	Static bending: Modulus of elasticity[c] (×10⁶ lbf/in²)	Static bending: Work to maximum load (in-lbf/in³)	Impact bending (in.)	Compression parallel to grain (lbf/in²)	Compression perpendicular to grain (lbf/in²)	Shear parallel to grain (lbf/in²)	Tension perpendicular to grain (lbf/in²)	Side hardness (lbf)
Pine—con.											
Pond	Green	0.51	7,400	1.28	7.5	—	3,660	440	940	—	—
	12%	0.56	11,600	1.75	8.6	—	7,540	910	1,380	—	—
Ponderosa	Green	0.38	5,100	1.00	5.2	21	2,450	280	700	310	320
	12%	0.40	9,400	1.29	7.1	19	5,320	580	1,130	420	460
Red	Green	0.41	5,800	1.28	6.1	26	2,730	260	690	300	340
	12%	0.46	11,000	1.63	9.9	26	6,070	600	1,210	460	560
Sand	Green	0.46	7,500	1.02	9.6	—	3,440	450	1,140	—	—
	12%	0.48	11,600	1.41	9.6	—	6,920	836	—	—	—
Shortleaf	Green	0.47	7,400	1.39	8.2	30	3,530	350	910	320	440
	12%	0.51	13,100	1.75	11.0	33	7,270	820	1,390	470	690
Slash	Green	0.54	8,700	1.53	9.6	—	3,820	530	960	—	—
	12%	0.59	16,300	1.98	13.2	—	8,140	1020	1,680	—	—
Spruce	Green	0.41	6,000	1.00	—	—	2,840	280	900	—	450
	12%	0.44	10,400	1.23	—	—	5,650	730	1,490	—	660
Sugar	Green	0.34	4,900	1.03	5.4	17	2,460	210	720	270	270
	12%	0.36	8,200	1.19	5.5	18	4,460	500	1,130	350	380
Virginia	Green	0.45	7,300	1.22	10.9	34	3,420	390	890	400	540
	12%	0.48	13,000	1.52	13.7	32	6,710	910	1,350	380	740
Western white	Green	0.35	4,700	1.19	5.0	19	2,430	190	680	260	260
	12%	0.38	9,700	1.46	8.8	23	5,040	470	1,040	—	420
Redwood											
Old-growth	Green	0.38	7,500	1.18	7.4	21	4,200	420	800	260	410
	12%	0.40	10,000	1.34	6.9	19	6,150	700	940	240	480
Young-growth	Green	0.34	5,900	0.96	5.7	16	3,110	270	890	300	350
	12%	0.35	7,900	1.10	5.2	15	5,220	520	1,110	250	420
Spruce											
Black	Green	0.38	6,100	1.38	7.4	24	2,840	240	739	100	370
	12%	0.42	10,800	1.61	10.5	23	5,960	550	1,230	—	520
Engelmann	Green	0.33	4,700	1.03	5.1	16	2,180	200	640	240	260
	12%	0.35	9,300	1.30	6.4	18	4,480	410	1,200	350	390
Red	Green	0.37	6,000	1.33	6.9	18	2,720	260	750	220	350
	12%	0.40	10,800	1.61	8.4	25	5,540	550	1,290	350	490
Sitka	Green	0.37	5,700	1.23	6.3	24	2,670	280	760	250	350
	12%	0.40	10,200	1.57	9.4	25	5,610	580	1,150	370	510
White	Green	0.33	5,000	1.14	6.0	22	2,350	210	640	220	320
	12%	0.36	9,400	1.43	7.7	20	5,180	430	970	360	480
Tamarack	Green	0.49	7,200	1.24	7.2	28	3,480	390	860	260	380
	12%	0.53	11,600	1.64	7.1	23	7,160	800	1,280	400	590

[a]Results of tests on small clear specimens in the green and air-dried conditions. Definition of properties: impact bending is height of drop that causes complete failure, using 0.71-kg (50-lb) hammer; compression parallel to grain is also called maximum crushing strength; compression perpendicular to grain is fiber stress at proportional limit; shear is maximum shearing strength; tension is maximum tensile strength; and side hardness is hardness measured when load is perpendicular to grain.
[b]Specific gravity is based on weight when ovendry and volume when green or at 12% moisture content.
[c]Modulus of elasticity measured from a simply supported, center-loaded beam, on a span depth ratio of 14/1. To correct for shear deflection, the modulus can be increased by 10%.
[d]Coast Douglas-fir is defined as Douglas-fir growing in Oregon and Washington State west of the Cascade Mountains summit. Interior West includes California and all counties in Oregon and Washington east of, but adjacent to, the Cascade summit; Interior North, the remainder of Oregon and Washington plus Idaho, Montana, and Wyoming; and Interior South, Utah, Colorado, Arizona, and New Mexico.

Tinius Olsen Manual