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ABSTRACT

The preliminary draft for a course in Strength of Materials and Materials Testing Laboratory contains a day by day teachers guide and an outline for laboratory activities. The guide includes sequence of topics, suggested reading assignments, demonstrations, and worksheets. The outline provides material for the development of a laboratory manual and contains explicit suggestions as to content, sequence, and type of activities. Major topics are forces, moments, simple stresses, riveted and welded joints, beams, centroids, moment of inertia, flexure formula, and shear stress. [Not available in hardcopy due to marginal legibility of original document.] (DS)

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CURRICULUM PROJECT REPORT

Preliminary Material
Limited Distribution

APPLIED PHYSICS LABORATORY

Strength of Materials

High School

12th Year

(Incomplete)

Project No. 8017

These experimental curriculum materials were prepared as part of the Curriculum Workshop Program of the Bureau of Curriculum Development.

July 1970

BUREAU OF CURRICULUM DEVELOPMENT
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131 Livingston St., Brooklyn, New York 11201

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STRENGTH OF MATERIALS

An Experimental Program as part of the Applied Physics Laboratory for High Schools, 12th year.

These materials (at present-incomplete) constitute a preliminary draft for a course in Strength of Materials and Materials Testing Laboratory.

ACKNOWLEDGMENTS

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Dr. Daniel A. Salmon, Assistant Director, Bureau of Curriculum Development, served as coordinator of the Curriculum Development Workshop Programs.

The original manuscript was prepared by:

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These materials are being distributed to selected high schools for tryout and evaluation. Suggestions for modification of the final publication are solicited and should be returned by June 1, 1972 to:

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CONTENTS

APPLIED PHYSICS LAB - STRENGTH OF MATERIALS

Introduction

Discuss the nature of strength of materials; the loads imposed on structural members and parts of aircraft; the necessity of determining the strength of the materials to resist loads.

Review and re-define basic terms such as length, area, volume, force, pressure, mass, weight, density, work, power. Review the difference between scalars and vectors and how force is represented (magnitude, direction, and point of application)

I. Forces
Ref. 5-Chap.2
1. Intro-duction
(a) Definition

Demomstrate (a) a weight suspended by a wire and (b) a rigid body (wood or metal) supported at two ends with a wieght resting between supports.

Discuss the forces involved. Establish the difference between an external and internal force. Correlate this to action and reaction.

Show this visually by means of simple force diagrams and point out the meaning of Collinear Forces, Concurrent Forces, and Coplanar Forces.

Discuss the effect of a weight or force on various types of materials (elastic and non-elastic). What do we consider a rigid body?

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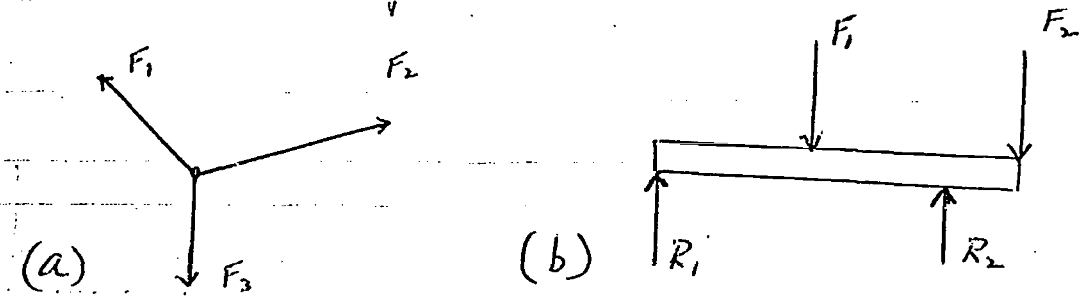
2. Types of Force Systems

Demonstrate (a) a force board (Physics Lab material) and (b) a suspended meter stick with 2 supports and weights and different positions.

Develop force diagrams with class:

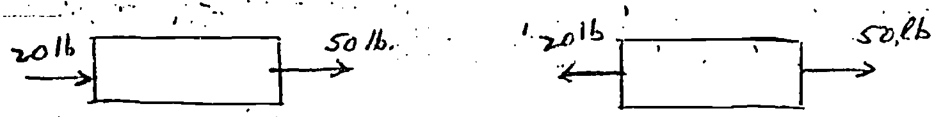


Discuss the lines of action of the forces and their points of application. The class to determine which system is concurrent - coplanar and which is non-concurrent coplanar.

3. Vectors

Review the representation of forces as vectors.

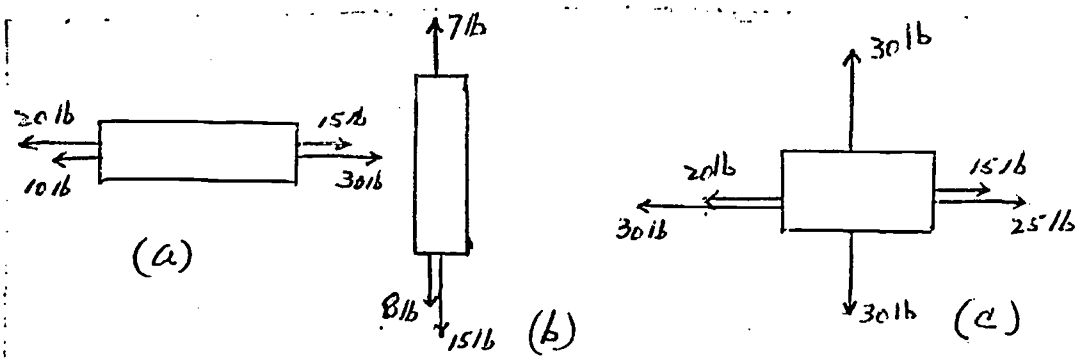
Present several simple collinear force problems as:



a) Resultant

Have the class determine the resultants. Emphasize the significance of the resultant. Establish the standard of a direction to the right as positive and direction to the left as negative. (up as positive and down as negative).

Present problems in the collinear force systems such as:



Students to determine Resultants in X direction (Rx) and in Y direction (Ry)

b) Equilibrant

Initiate the concept of Equilibrium.

What is the resultant in case (a)

How could we keep it from moving?

What is an Equilibrant?

What is the condition for equilibrium?

Develop this similarly for case (b) and (c).

Present the problem of 2 concurrent forces at 90°.

Review and demonstrate with class participation the graphical and mathematical methods of obtaining the resultant. Establish the difference between the resultant and the equilibrant. Emphasize static equilibrum conditions.

Show graphically how the angle between the concurrent forces affects the resultant.

c) Resolution

By means of a vector diagram show how the resultant is obtained from 2 perpendicular forces. Now reverse the procedure and show how this resultant force can be replaced by its 2 component forces.

Introduce the use of the sine, cosine, and tangent functions to obtain the x and y components of any force. Use an illustrative

problem such as a 4800 lb. force at an angle of 30° with the horizontal. Show how the x and y components are obtained. 4

Use an inclined plane problem to show how the x and y axis can be shifted to parallel and perpendicular to the board, thus obtaining the components of the weight of a body parallel and normal to the inclined plane.

d) Resultant by Summation

Present an illustrative problem on the blackboard of 3 or more concurrent forces at different angles to the horizontal. (see worksheet). Generate a class discussion as to the method of obtaining the resultant. Guide the discussion to the summation of all the x components and all the y components with the ultimate conclusion: $R^2 = F_x^2 + F_y^2$

With another illustrative problem and class participation show how an orderly approach and procedure can simplify finding the resultant of concurrent forces by summation.

It would probably be helpful to use a table such as:

Force	Angle	Sin	Cos	Fx	Fy
F_1	30°	.5	.87		
F_2	45°	.707	.707		
etc.					

$$\Sigma F_x =$$

$$\Sigma F_y =$$

$$R = \sqrt{F_x^2 + F_y^2}$$

Demonstrate the use of the trig table to determine the angle of the resultant as: $\tan \theta = \frac{\Sigma F_y}{\Sigma F_x}$

Several problem sessions are in order at this point so that the procedures and mechanics of problem solving might be reinforced. See worksheets.

Forces - Worksheet

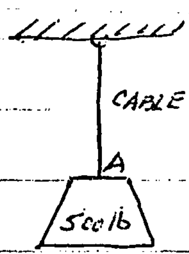


FIG. 1

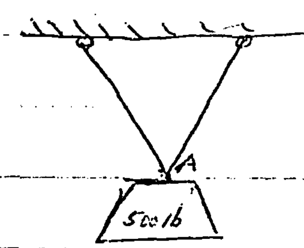


FIG. 2

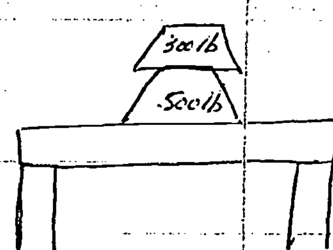


FIG. 3

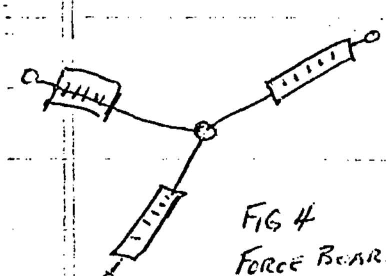


FIG 4
FORCE BOARD

FIG. 5

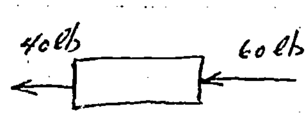
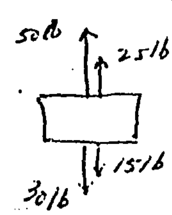


FIG. 6

Fig. 7



WORKSHEET — FORCES

6

1. Make diagram showing forces acting on point A

   in Fig. 1 in Fig. 2 in Fig. 3

2. What is the external force on the cable in Fig. 1?

3. What is the internal force in Fig. 1?

4. What are a) Collinear forces - in which diagram?

   b) Concurrent forces - " " "

   c) Coplanar forces - " " "

5. Which figure shows Concurrent-Coplanar force System?

6. Which figure shows Noncurrent-Coplanar force System?

7. In Figures 5 - a) What type of force system?

   b) What is the magnitude of the resultant?

   c) What is the direction of the resultant?

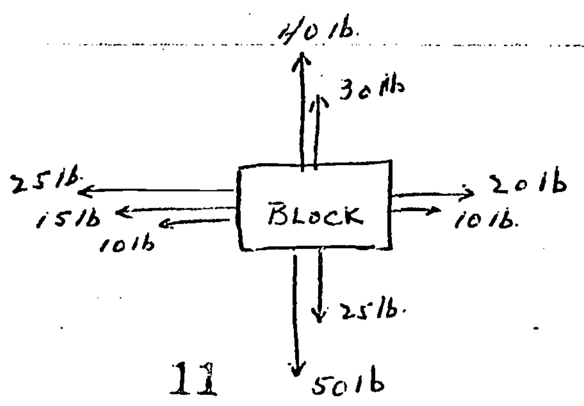
   d) Is it positive or negative?

8. In Figure 6 what single force can replace those shown?

   In which direction?

9. In Figure 7, find the resultant of the collinear forces shown.

Fig. 8



10. In figure 8, a) Find the resultant in the x direction.

b) Is it positive or negative?

c) Find the resultant in the y direction.

d) What force must be applied in which direction to keep block from moving in an x direction?

e) What force must be applied and in which direction to keep block from moving in a y direction?

f) What are the forces of (e) and (d) called?

11. There are two forces acting on a Rivet. One force is 40 lb. East and the other force is 30 lb. North.

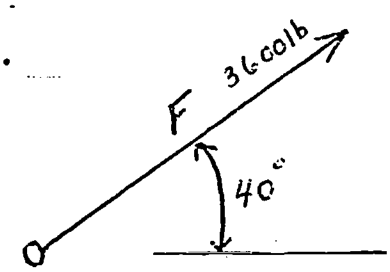
a. What is the difference between a scalar and a vector quantity?

b. Are these forces concurrent or non-concurrent? Why?

c. Draw the vector diagram.

d. Find the resultant (magnitude, direction, point of application).

e. What is the equilibrant?

12. 

As shown, force F is applied at point O at an angle of 40° with the horizontal.

a. Make a drawing showing the x component (F_x)

b. Show the y component (F_y)

c. Calculate F_x and F_y ($F_x = F \cos \theta : F_y = F \sin \theta$)

(Get cosine and sine values from Trig table)

d. When is the x component of a force positive? and when negative?

e. When is the y component positive and when negative?

13. Four forces act through a common point at right angles to each other. One force is 100 lb. East; one is 200 lb. North; one is 400 lb. West; and one is 600 lb. South.

a. Find the vertical component.

b. Fine the horizontal component.

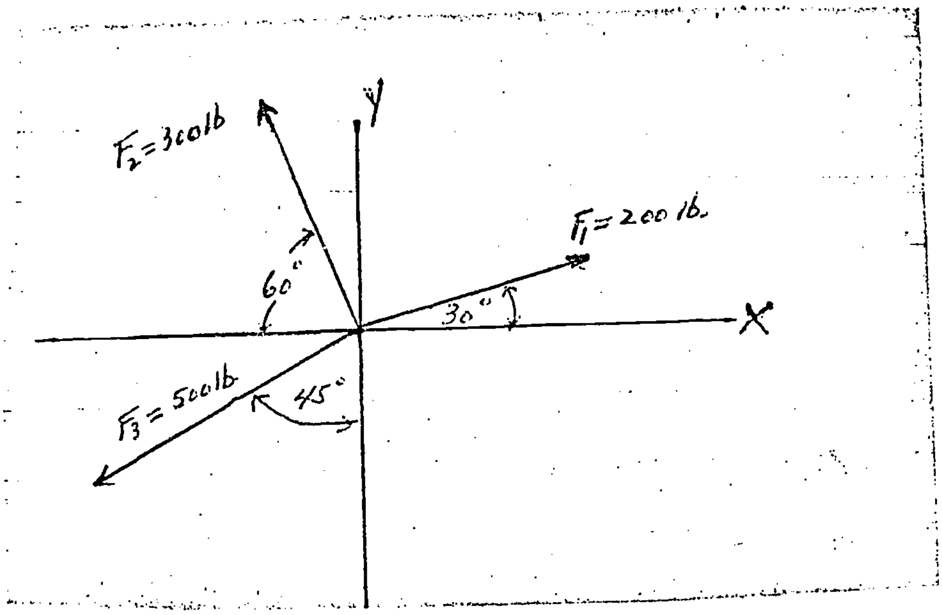
c. Find the size and direction of the resultant force.

14. A force is acting at 30° to the horizontal. Its vertical component is 400 lb.

a. What is magnitude of the force?

b. What is the horizontal component?

15.



a. Find F_{1x}, F_{2x}, F_{3x}

b. Find F_{1y}, F_{2y}, F_{3y}

c. Complete the following table:

	Force	X	Sin X	Cos X	X:	Force Components			
						+	-	+	-
F_1	200#	30°							
F_2	300#	60°							
F_3	500#	45°							

d. Find algebraic sum of x components (magnitude & direction)

e. Find algebraic sum of y components (magnitude & direction)

f. Find the resultant (apply the the pythagoream theorem)

g. What is direction of the resultant?

$$\left(\tan \theta = \frac{\Sigma Y}{\Sigma X}\right)$$

16. Find the x and y components of a force of 6800# which is directed upward to the right at an angle of 60° with the horizontal. /c

17. Find the x and y components of a force of 390# which is directed upward to the left at an angle of 48° with the horizontal.

II. Moments

Demonstrate examples of turning or pivoting. (Hold finger at one end of book lying on the table and push at other end to pivot book: Show a pivoted stick; a see-saw arrangement; a crank handle; etc.)

Generate a class discussion on what produces or tends to produce a turning effect at the pivot point or axis.

Show a balanced meter stick with weights at both sides of the fulcrum. Demonstrate how changing the moment arm requires different weights to balance the load.

Show how the load on the lever can be balanced by variations of the moment arm and the applied force. Elicit the relationship of these two.

a) Definition

Summarize with a definition of a moment of force and how it is measured.

Request examples of practical applications. (Turning of revolving door, shafts, crowbars, etc.)

Establish need for standard of reference for direction of notation. Explain the accepted standard of clockwise motion as a positive moment and counter-clockwise as a negative moment. Emphasize that the moment of a force about an axis is multiplied by the perpendicular distance from the axis to the force.

Illustrate how no moment results when the line of action of the force is parallel to the axis; how the moment depends only on the component of the force which is perpendicular to the moment arm.

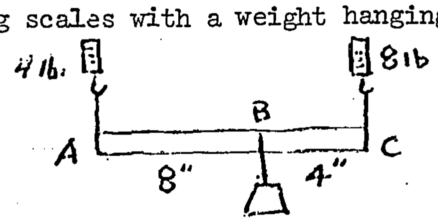
b) Equilibrium

Demonstrate with a balanced lever the condition for rotational equilibrium; sum of the clockwise moments equal the sum of the counter-clockwise moments.

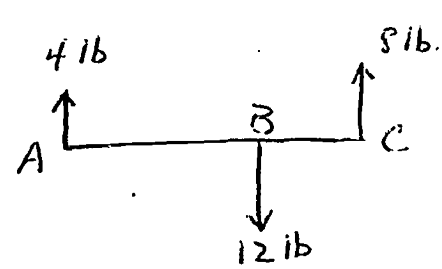
c) Parallel Forces

Show a light rod or meter stick suspended at both ends by spring scales with a weight hanging somewhere between -

as:



Have the students construct a free-body diagram as:



Establish that forces whose lines of action are parallel are called parallel forces.

In discussion the class is to establish that for translation and rotational equilibrium. The $\Sigma F_x = 0$

$\Sigma F_y = 0 \quad (4 + 8 - 12 = 0)$

$\Sigma M = 0 \quad \Sigma M_a = (8 \times 12) - (12 \times 8) = 0$

Show how $\Sigma M_b = 0$

$\Sigma M_c = 0$

d) Conditions for Equilibrum

$\Sigma F_x = 0$

$\Sigma F_y = 0$

$\Sigma M = 0$

Summarize the conditions for equilibrium.

1. Algebraic sum of the forces must be zero
2. Algebraic sum of the moments about any point must equal zero.

Problem sessions should be held to reinforce the conditions for equilibrium and the means of solving problems. (See worksheet.)

Several illustrative problems should be shown. Include the practice of drawing free-body diagrams and show how a uniformly distributed load of a beam may be considered acting at the center of gravity.

From this point on, at the discretion of the instructor, more complex beam problems may be treated, such as those involving:

Beams with uniformly distributed loads together with

Concentrated loads

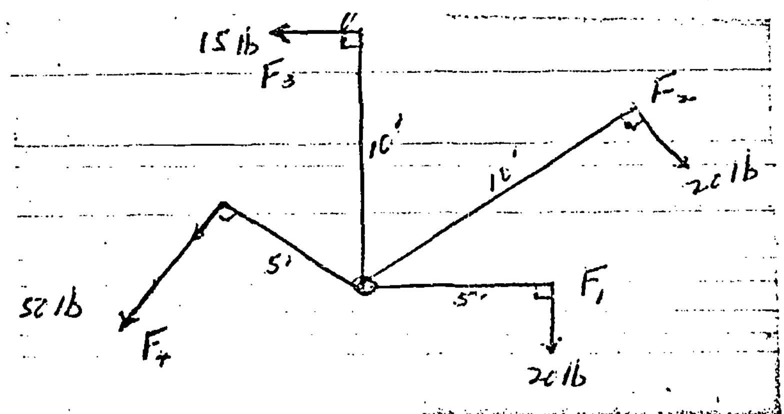
Overhang beams

Beams with uniformly distributed loads over a portion of their length.

WORKSHEET — Moments

1. What is the moment of a force?

2.



About point O, what is the (use proper units)

a) moment of F_1

b) moment of F_2

c) moment of F_3

d) moment of F_4

e) What is the sum of the moments about point O?

f) If F_4 were eliminated what would be the sum of the moments about point O?

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3.

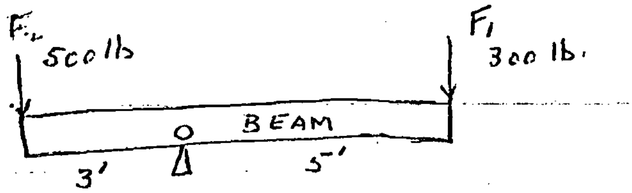


Figure shows a beam pivoted at O

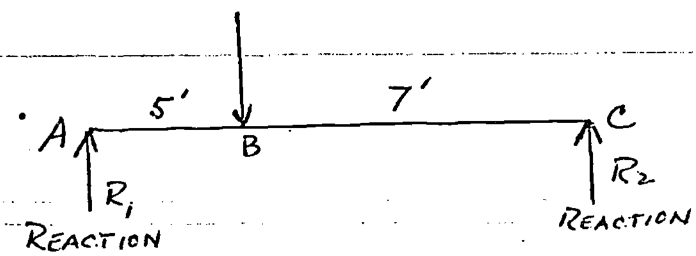
a) Find the moment of F_1 about point O and its direction

b) Find the moment of F_2 about point O

c) Will the beam be balanced?

d) What is the upward reaction of the pivot on the beam?

4.



a) Find R_2 by taking the sum of the moments about A

b) What is the moment of R_1 about A?

c) Find R_1 by taking the sum of the moments about C.

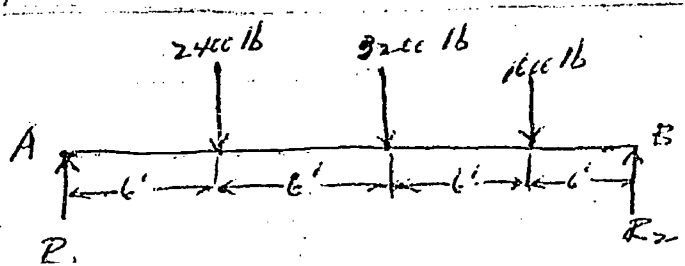
d) What is the moment of R_2 about C?

e) Why was point A chosen as the moment center to find R2?

f) What must the sum of R_1 and R_2 equal if the beam is in equilibrum?

g) What are the conditions for equilibrum?

5.



BEAM with 3 LOADS

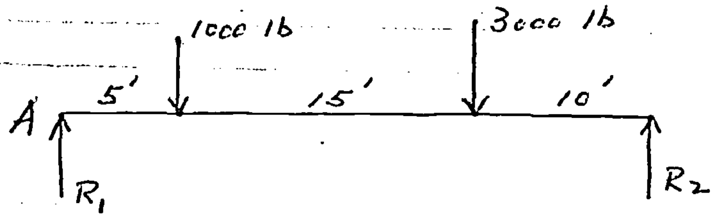
a) Find R_2 by taking the sum of the moments about A. 15

b) Find R_1 by taking the sum of the moments about B.

c) Are the conditions for equilibrum satisfied?

d) Can you find R_1 without doing (b)? How?

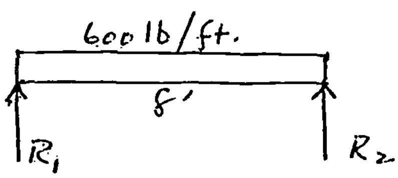
6.



A beam resting on 2 end supports carries concentrated loads as shown.

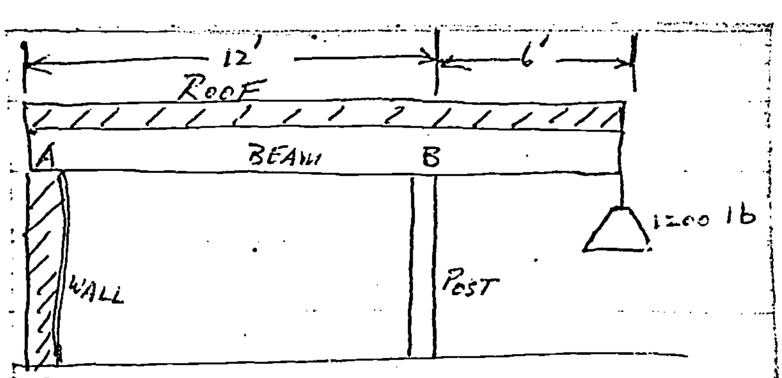
Find R_1 and R_2

7.



Find R_1 and R_2

8.



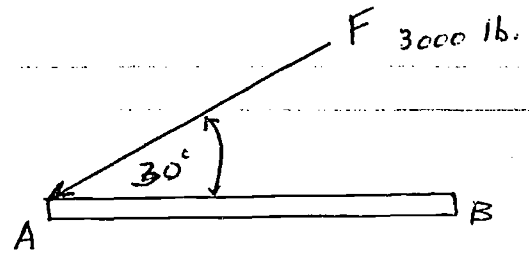
The beam supports a roof which weighs 300 lbs. per foot of length of beam 16

and a concentrated load of 1200 lb. The beam is supported by a wall at A

and a post at B. Find the reactions at A and B.

First make a Free-Body Diagram.

9.



a) Find the moment of F_x about A

b) Find the moment of F_x about B

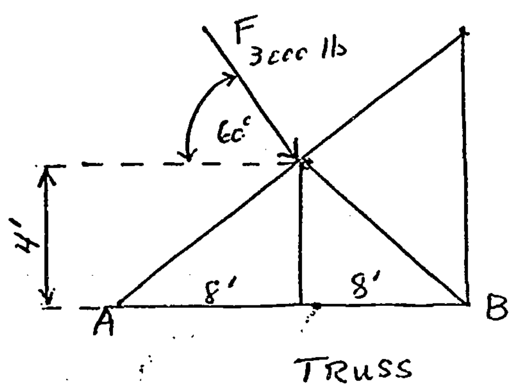
c) Find the moment of F_y about A

d) Find the moment of F_y about B

e) Find the moment of F about A

f) Find the moment of F about B

10.



Find the moment of the 3000 lb force F about point B.

III. Simple Stresses

Suspend a weight by a string. What is e action of the weight on the string? The string on the weig . Discuss the internal resistance of the string to the force applied to it. Cite other examples such as hanging from a bar, sitting on a chair, etc. Show how in all cases there is an internal resistance to an external force.

Cut the string of the demonstration in half and fasten 2 spring balances in the break and again suspend the weight.

The class will note that each balance will indicate the value of the suspended weight, indicating that this value of force was required to hold the parts of the string together (the internal force of the fibers of the string).

a) Definition

Define stress.

b) Types

Ask for examples of stress and assort these answers in groups or types such as
a) tension - pulling apart
b) compression - pushing together
c) shear - cutting

c) Unit Stress

Show the same magnitude of weight suspended on wires of differing 18 diameters.

Discussion as to the equality of the forces acting on each wire and the difference of the area over which it acts.

Is each wire subjected to same or different stresses? Why?

How is the load or force distributed over the cross-sections of each wire? Which wire can support a greater load?

Define unit stress as $S = \frac{F}{A}$.

Emphasize the use of the units as psi.

Through the use of several illustrative problems show how to obtain S, F, or area, in tension, compression, and shear.

Demonstrate the technique of analysis by using a given size (of a member) and material to obtain the load allowed. Show the design approach by finding the size of member required to satisy loading.

Work Sheet - Stress

1. A steel rod has a cross sectional area of 2 sq. inches and is subjected to a pull of 12,000 lb.

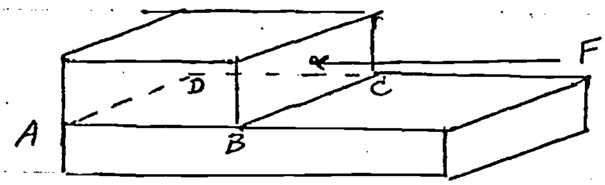
   a) What is the stress?

   b) Is it compressive, tensile, or shear?

2. A bar 4" x 4" and 6" long is under a compression force of 10,000lb.

Find the stress.

3.



What will be the shearing stress on the area A B C D? F is 2000 lb.

AB = 10", BC = 5"

4. A circular brass rod is to carry a tensile load of 10,000 lb. and its stress is not to exceed 7500 psi. What diameter rod is required?

5. If the diameter is doubled, what tensile load can be carried?

d) Double Shear

By use of an illustrative problem show the difference between single and double shear.

e) Strain

Demonstrate the deformation of a block of rubber (rubber eraser) under a compressive and tensile load.

What happens to the physical dimensions of the body?

What is this deformation called? Define strain.

How is strain affected if external force is changed?

Demonstrate Hooke's Law

Have class take data and draw a curve.

Establish that the strain is proportional to the stress causing it. 2c

Discuss compressive, tensile, and shear strains.

f) Unit Strain

Discuss a hypothetical test in tension. (Example: Start with 10" long steel bar which measures 10.10" while under tensile stress of 10,000 lbs.)

What was the total elongation e?

How much did each single inch elongate? Why?

Establish that the unit strain or deformation $E = \frac{e}{l}$

Discuss a hypothetical test in compression. (Example: A block of wood, originally 16" long is compressed by an amount of 0.034". Find the unit strain.)

Summarize:

1. Define stress and strain

2. Define unit stress and unit strain

3. How each is calculated.

<u>Worksheet - Strain</u>

1. A steel ROD 30 ft. long under tensile stress is used to support part of balcony. Under load the rod stretched to 30.15 ft.

   a) What was the strain (elongation) in inches?

b) What was the unit strain?

g) Stress-Strain Relationship

Ref. 2 - Chap. 3
Ref. 5 - Chap. 8

Explain and then demonstrate a tensile test of steel. This is to be a sample Laboratory exercise.

Instructions for Lab reports is explained and outline procedure is emphasized.

As data is plotted, full instructions are explained.

Test specimen is sketched and initial data noted.

Observed data of load vs. elongation is noted.

The calculated data is then obtained:

Stress vs. Strain

Psi vs. in/in.

The curve is plotted through class participation.

Explain the importance of knowing what to do and the reason for doing it before doing any Lab assignment; how the procedure is written.

Outline final data sheet and demonstrate calculations. Show standard page format.

h) Analysis: Properties of Material

With class participation, trace the stress-strain curve and discuss, analyze, and interpret the significant sections of the curve.

This activity should be so extended as to cover, in detail, the significant properties of materials, such as:

a) Hooke's Law

b) Modulus of Elasticity

c) Proportional Limit: Elastic Limit

d) Yield Point

e) Ultimate Strength

f) Breaking Point

g) Ductility as measured by per cent reduction in area and per cent elongation.

1. Modulus of Elasticity

Generate class discussion on the modulus of Elasticity by questions such as:

1. What is Hooke's Law?
2. Is there any evidence of this law on the curve?
3. What is the slope of the straight-line portion of the stress-strain curve?
4. What is this ratio called?
5. What is elasticity?
6. How is the modulus of Elasticity a measure of the stiffness or rigidity of a material?

Show the mathematical relationship involved:

$$E = \frac{S}{\epsilon} = \frac{P}{A} \times \frac{l}{e}$$

Discuss the practical uses of E and show with illustrative problems how it is used. Demonstrate the use of tables of properties of materials.

Drill Problems

1. A rectangular steel bar, 2" x 3/4" in section and 12' long, is subjected to a tensile force of 20,700 lb. How much does it stretch? (Find the modulus of steel in the tables.)

2. A steel column, 12' long, carries a load of 276,000 lb. The area of the cross section is 22 sq. in. How much does the column shorten?

2. Other Properties

Discuss, via interpretation of the stress-strain curve, the physical significance of Elastic Limit, yield point, ultimate strength and rupture point.

Explain ductility and show how to calculate the per cent reduction of area and per cent elongation.

3. Factor of Safety

What conditions affect the safety of a structual member?

In what range of stress is a material safe?

Why does a design engineer select a 1 sq. in. section rather than $\frac{1}{2}$ sq. in. or 2 sq. in. for a particular material?

How does he know how to prevent future or permanent deformation of the material? How does he know if it is safe for the load?

Discuss ultimate strength and why the maximum allowable stress must fall within the elastic range. Describe use of allowable, safe working, or design stresses.

To ensure a safe design, show the use of a safety factor with actual figures for a particular load and material.

Example: The ultimate strength of structual steel in tension is 60,000 psi (where do we get this figure? How is it obtained?) The working stress for the particular use is 18,000 psi.

$$\text{factor of safety} = \frac{\text{ultimate strength}}{\text{working stress}} = 3.33$$

Discuss the prevalent use of allowable stresses as specified by codes and the use of different values of factors of safety as related to different materials and uses.

Worksheet (Stress-Strain)

1. A standard .505" specimen of steel was tested, resulting in the following data:

original gage length	= 2.0"
Final gage length	= 2.314"
Diameter at Rupture	= 0.378"
Load at Elastic Limit	= 12,500#
Ultimate Load	= 15,450#
Elongation $e_{E.L.}$	= .00452

a) Calculate the unit stress at elastic limit

b) The ultimate stress

c) The per cent elongation

d) The per cent reduction of area

2. A force of 10,000 lbs. deforms a 3/8" diameter x 2" long specimen 1/8 in.

a) What is the unit strain developed?

b) The unit stress?

3. If a steel rod, $\frac{1}{2}$" dia. x 2" long develops a unit strain of 0.0600 in./in. when under stress, how much has it deformed?

4. If an aluminum rod of a given size develops a unit strain of 0.0450 in./in. under stress, what must be its length in order that it deform 0.189"?

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5. A square wood post is to carry a compressive load of 92,000 lbs. with a working stress of 1200 psi, what size of post is required?

6. Bolt in shear

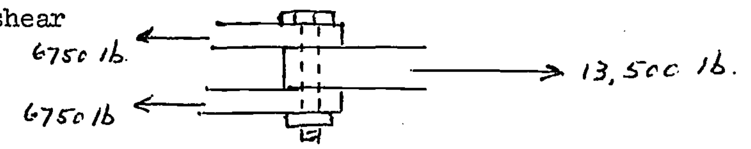


Figure shows 3 plates held together by a bolt. The working stress for the bolt in shear is 10,000 psi. What diameter of bolt is required?

7. A 1" square steel bar x 16" long elongates 0.0111 in. when subjected to a tensile force of 20,500#. Compute the modulus of elasticity.

   a) What is the unit stress?

   b) Is it less than the elastic limit?

   c) Is the formula $E = \frac{Pl}{Ae}$ valid?

8. A steel bar 2" dia. x 10' long is subjected to a tensile force of 60,000 lb. Compute its deformation.

   a) What is the cross sectional area of the bar?

   b) What is the unit stress?

   c) Is this less than the elastic limit?

   d) Is the formula $e = \frac{Pl}{AE}$ applicable?

9. What safe load may be placed on a 4' 6" x 4' 6" concrete column footing if the bearing capacity of the foundation bed is 5 tons per sq. ft.?

4. Temperature Stresses

Demonstrate the expansion of a metal rod upon the application of heat with one end constrained.

What happens if both ends are constrained?

Discuss the coefficient of linear expansion, what it means and how it is computed.

What kind of stresses are set up if body is constrained?

Show a table of coefficents of expansion and discuss the effect of change of temperature on stresses in different materials.

What means are used in structural design to avoid these stresses?

With an illustrative problem show the means of calculating the total deformation due to a temperature change.

$$e = ct\ell$$

Develop this: $\frac{e}{\ell} = ct = \varepsilon \quad \therefore E = \frac{S}{\varepsilon}$

$$S = E\varepsilon = Ect$$

Show a practical application of this relationship with an illustrative problem.

Ref. 2 - Page 27

Ref. 5 - Page 130

IV. Riveted and Welded Joints

Several individual structural members must be connected.

How is this done?

1. Structural Connections

Discuss connections such as bolts, rivets, and welds.

Explain that the usual procedure in designing a structure is to design the members first, and then to design safe connections between these members.

2. Riveted Joints

What are rivets? bolts?

Show a specimen of a riveted and bolted joint.

a) Types of Joints

Discuss how riveted and bolted assemblies are made and the various types.

If possible, show types of joints such as single lap, double lap, butt joint, single riveted and double riveted lap joints.

Draw on board diagrams of various types of joints.

b) Types of Failures

How can a riveted joint fail?

With appropriate diagrams, discuss the types of failure such as shear in the rivet, the possibility that the plate may pull apart at its weakest section, and bearing (crushing) of the rivets or plate material in contact with the rivets.

Review single and double shear.

c) Stresses in a Riveted Joint

What kind of stresses are developed in a riveted joint?

d) Calculations

Illustrate with diagrams tension in plate, shear in plate, shear in rivet, and bearing in plate.

Show how the load is calculated for each of these stresses and summarize (Ref. 2 - page 42)

How is a safe load calculated? Why should it be the lowest of the stresses? Show the use of allowable unit working stresses.

Demonstrate the handling of illustrative problems.

Summarize the procedure of calculating a safe load:

1. Draw the joint and include all pertinent dimensions as: dia. of rivet (or bolt), edge distance, pith, thickness of plate, width of plate.

2. Calculate the areas of the various types of stresses.

3. Calculate the safe load for each stress.

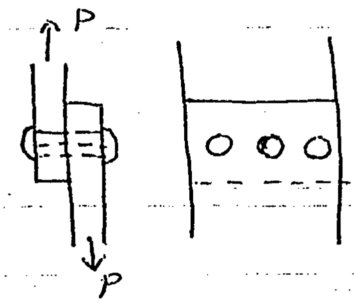
Compare the handling of a lap joint with that of a butt joint. Clarify with illustrative problem.

Drill problems should be assigned to re-inforce the procedures of handling the various riveted joints, terminology and codes.

3. Efficiency What is meant by the efficiency of a riveted joint and how is it determined? Discuss the relationship of an ideal joint (no joint or solid plate) and the actual safe load of the joint. Show how efficiency is calculated. Demonstrate with an illustrative problem.

Worksheet - Riveted Joints

1. The load on riveted joint as shown is 16,400 lbs. The rivets are 3/4" dia.



   a) What is the area in shear?

   b) What is the shearing stress?

   c) Is rivet in single or double shear?

2.

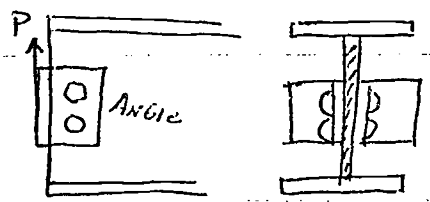


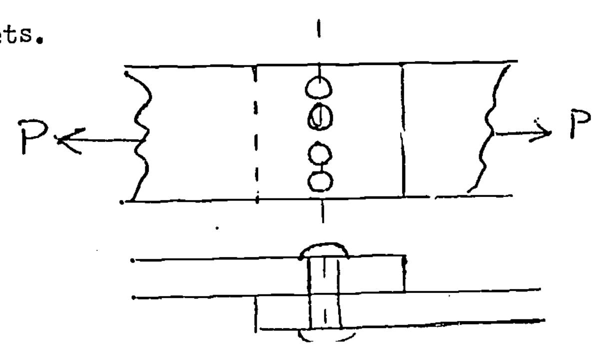
Figure shows two angles riveted to the web of a beam. The rivets are 7/8" dia. and the load is 37,600 lbs.

   a) Are the rivets in single or double shear?

   b) What is the area of one rivet in shear?

   c) Calculate the shearing stress.

3. A single reveted lap joint with 12 by $\frac{1}{2}$ in. plates contains four 7/8 in. dia. rivets.



The allowables stresses are:

$S_s = 15,000$ psi

$S_t = 20,000$ psi

$S_c = 32,000$ psi

Find the largest load that this joint can safely carry.

a) Find the largest safe load in shear, tension, bearing.

b) Which is the least of these calculated loads?

c) What is the largest safe load?

d) What is the strength of the joint?

4. Welded Joints

Show class examples of welded joints. Review the process of fusion welding.

a) Types

Describe the types of welded joints. Discuss how they can fail. Clarify, by use of diagrams, the side fillet, end fillet, and butt welds.

With illustrative problem show how to determine the shear area of a weld, the use of allowable loads for fillet welds, and the length of the weld.

Develop the formula, $F = 600\ N\ L$ for the allowable force on a fillet-welded joint for structural steel, where F is the allowable force, N is the number of sixteenths in a weld leg, and L is the total length of fillet welding in inches.

Demonstrate the use of the formula with several illustrative problems.

Describe different kinds of butt welds and discuss how the strength of such welds are determined. Use illustrative figures.

Worksheet - Welded Joints

1. A lap-welded joint is to resist a pull of 50,000 lb. The plates are ½" thick. What must be the length of each of the two side welds?

   a) What sixe fillet weld does a side weld for ½" plate require?

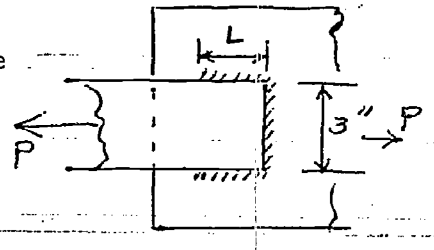
   b) What is the total length of weld needed?

   c) What is the length for each side?

2. Two 3/8" plates are fillet welded. The length of each fillet is 6". If 3/16" welds are used what is the allowable strength of the joint?

3. In the figure the force is 36,000 lb.

The upper plate is 3/8" thick and the fillet weld is 3/8". Find the length L.



4. Two plates $7\frac{1}{2}$" wide x 7/16" thick are to be connected by means of a butt weld. What is the strength of this weld?

a) What is the allowable tensile stress?

b) What is the area of tensile stress?

c) What is the strength of the weld?

V. Beams

/. Reactions

What is a beam?

a) Introduction

Discuss the members of a structure and the difference between columns and beams.

On the blackboard show a beam supported at both ends with a concentrated load at the center. Discuss and review free body diagrams, reactions and conditions for equilibrium.

As part of the review do several problems on blackboard involving a combination of uniformly distributed loads and concentrated loads on simple beams.

b) Types

Show by means of diagrams on the blackboard examples of a simply supported beam, overhanging beams and a cantilever beam.

Discuss and define the types of beams. Show the free body diagrams for each type.

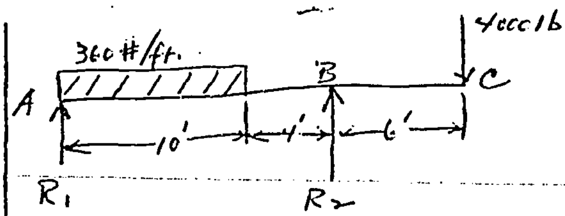
c) Reactions

Drill problems to develop the understanding of calculating forces and moments in statically determinate beams. Use worksheets and text problems.

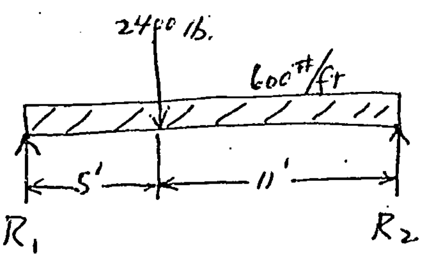
Worksheet - Beam Reactions

Find reactions R_1 and R_2 for the following problems.

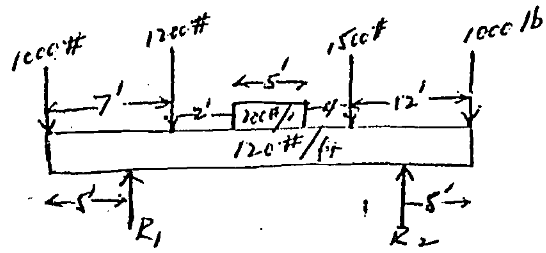
1.



2.



3.



2. Vertical Shear

Review the action of shear with diagrams on the blackboard. Discuss the direction of the forces in each case and the effect of the distance between them. At any particular section discuss why the sum of the opposite forces must be zero.

Define the shear force at any section as the algebraic sum of all the external forces acting on the beam to the left of that section.

Illustrate the calculation of the vertical shear force with free body diagram computations of concentrated and uniformly distributed loads. With several sample problems show how to make a shear force diagram (preferably under the free body diagram). Explain in the procedure how this is a plot of the net external shearing forces which act at each beam cross section which are caused by the loading on the beam.

Develop a shear diagram for a simply supported beam with a concentrated load, a uniformly distributed load, and a combination of both.

Go through an analysis of the shear diagram and emphasize the points to note and how the diagram changes and the reasons for the changes.

Worksheet - Vertical Shear

1. What is a beam?

2. How do you find the reactions on a beam?

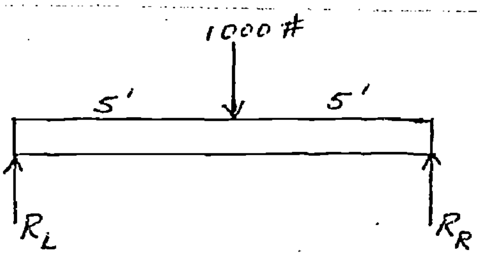
3. What is the shearing force in a beam?

4. What is a shear diagram?

5. When is a shear diagram line (a) horizontal? (b) a sloping line?

6. The figure shows a simply supported beam with a concentrated load at the center. Neglect the weight of the beam.

Ref. 5-
p. 190

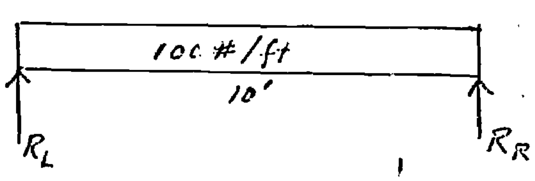


a) Find the shear forces.

b) Sketch the shear-force diagram for this beam under the free body diagram.

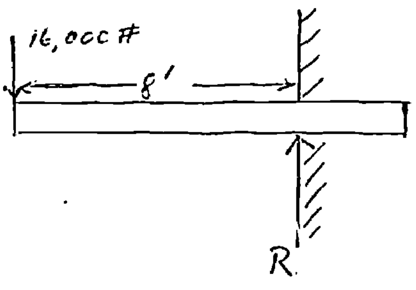
7. Find the shear forces and sketch the shear-force diagram for this beam under the free body diagram.

Ref. 5-
p. 191



8. Determine the shear diagram for the cantilever beam shown in the figure. Neglect the weight of the beam. (Cantilever beams should always be sketched with the free end to the left.)

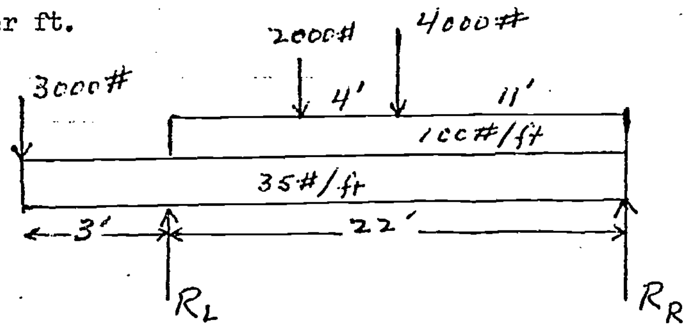
Ref. 5-
p. 191



9. Use same cantilever beam as in problem 8 and replace the concentrated load with a uniform load of 200 lb. per ft. Determine the shear diagram.

Ref. 5-
p. 192

10. Determine the shear diagram for the over-hanging beam shown. The beam weighs 35 lb. per ft.



Ref. 1-
p. 59

11. Draw the shear diagram for the beam of Figure 1.

Ref. 1
p. 59

12. Draw the shear diagram for the beam of Figure 2.

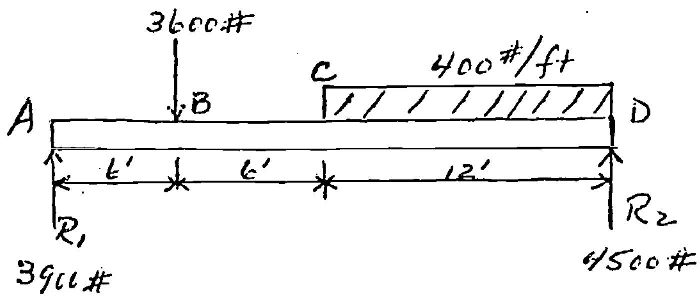


FIGURE 1

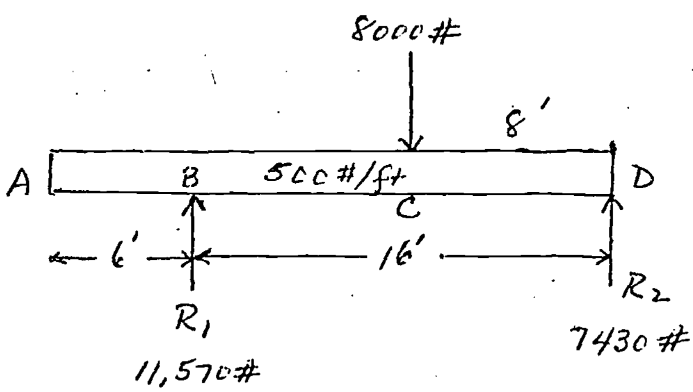


FIGURE 2

3. Bending Moment

Consider a 12 ft. long plank bridging a 10 ft. wide stream. As you cross it what happens to the plank?

What causes this bending?

Would a beam in an airplane, in a building, or a shaft tend to bend under load?

Would the plank bend as much if the span were 5 ft.? What causes the greater bending in the longer span?

Guide the class discussion to a simple analysis of the bending effect of the external forces at any particular section.

Show a simple span with a concentrated load. Question the effect of the reactions about a particular section. Determine the relationship of the clockwise and counterclockwise moments about this section. Continue this analysis with other sections. Where does the maximum bending occur?

Show the bending-moment diagram as a plot of the net external moments which act on the beam at each section. Explain that the beam material must resist these moments in order to maintain equilibrum. Discuss this importance in designing a beam for a given load.

Do several sample problems on the blackboard to familiarize the class with the procedures of calculation and plotting.

Use a simply supported beam with a concentrated load and show the free body diagram, the shear force diagram and the moment diagram.

Repeat this for (a) a simply supported beam with a uniformly distributed load

(b) A cantilever beam with a concentrated load at the free end and neglecting the weight of the beam

(c) A cantilever beam with a uniform load for the entire length.

(d) A single overhanging beam

(e) A double overhanging

Drill problems should be assigned to develop the understanding and skill of determining moment diagrams.

4. Relationships: Beam Loading Shear Diagram Moment Diagram

Examine and discuss the diagrams of beam loading, shear, and moment of the previous illustrative problems. In the discussion it should be observed and noted that the moment diagram is a straight line for any part of the beam where there are no forces and a parabola for any part where there is a uniformly distributed load.

Have the class note how useful the moment diagram is to see how the bending moment varies across the beam; where the maximum is and how much it is. Students will readily see the coincidence of maximum bending with zero shear.

Point out the cases of concentrated load all having a horizontal line in shear diagram and a sloped straight line in the moment diagram; in cases of uniform load, the shear line is sloped straight while the moment line is curved.

Depending on the judgement and discretion of the instructor the following areas of instruction may follow:

1. The mathematical relationship between a bending moment at a given section in a beam and the area of the shear diagram from the end of the beam to that section.

2. Developing the handbook formulas for the most commonly loaded beams.

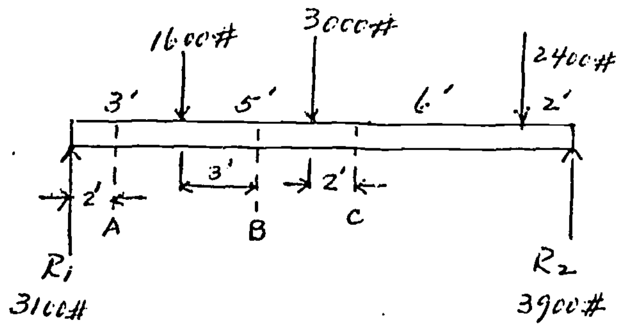
Worksheet - Bending Moment

1. What is a bending moment?

2. What is a moment diagram?

3. When is the moment diagram (a) a straight line? (b) a parabola?

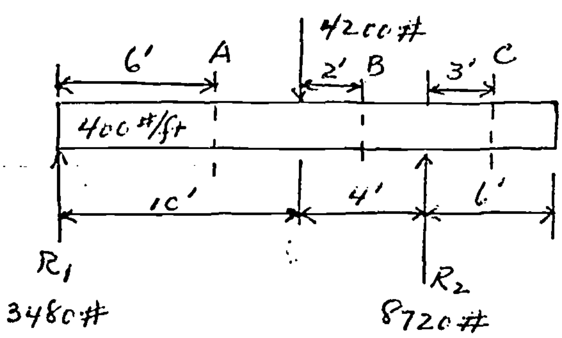
4. (a) In the beam shown, Calculate the bending moment at section A.



(b) Find bending moment at Section B

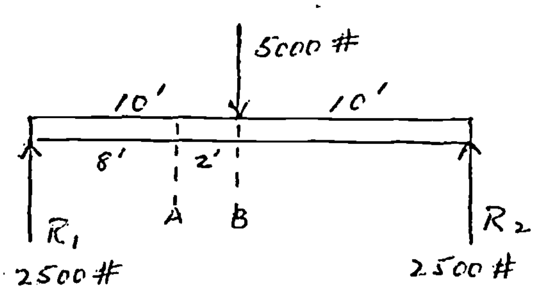
(d) Find bending moment at Section C

5.



Calculate the bending moments at Sections A, B, C.

6.



(a) What are the conditions for equilibrium?

(b) What force or forces would cause a cw rotation around Section A?

(c) What are the clockwise and ccw moments about Section A?

(d) What are the bending moment about Section A?

(e) What are the bending moment about Section B?

(f) What happens to the moment of force P?

(g) What is the bending moment cw about Section C?

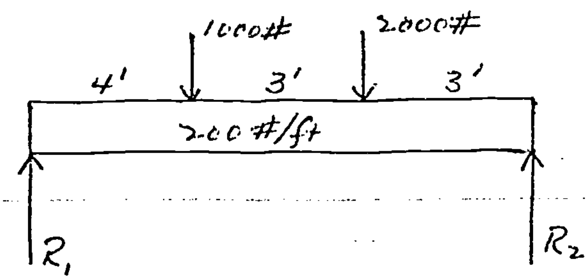
(h) CCW moments about Section C?

(i) Where does the maximum bending moment occur?

(j) Plot the shear diagram.

(k) Plot the moment diagram under the shear diagram.

7.



(1) Find R_1 and R_2

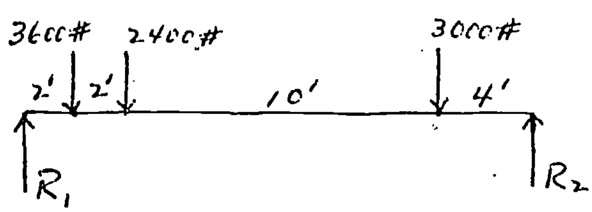
(2) Draw free body diagram

(3) Draw shear diagram

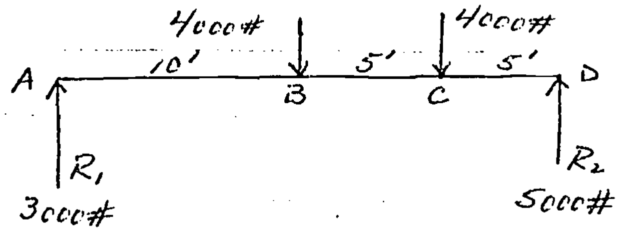
(4) Find the bending moments to left of each section taken at 1 foot intervals, starting with section at R_1

M_{R1} M_1' M_2' M_3' - - - - M_{10}'

8. Draw the moment diagram from the free-body diagram of the following beam.



9.



(1) Plot the shear diagram

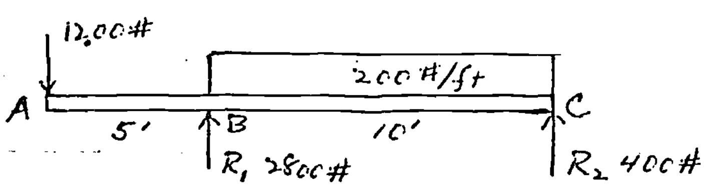
(2) Where does the maximum bending moment occur?

(3) How much is it?

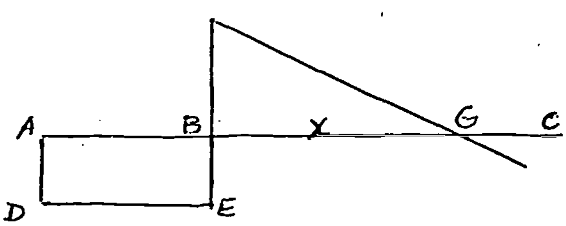
(4) At what point does the maximum bending moment occur?

(5) How much is it?

10.



FREE Body DIAGRAM



PART of Shear Diagram

(1) What is the value of D and F in the shear diagram?

(2) Where is the shear force zero?

(3) What is the shear at E? The bending moment at B?

(4) What is the shear at G?

(5) Locate point G.

(6) Find the bending moment at G.

(7) Where is the maximum bending moment?

VI. Centroids

1. Center of Gravity

Suspend a uniform rod by a string off center. Have a student move the string until the rod hangs honzontally. What is this point?

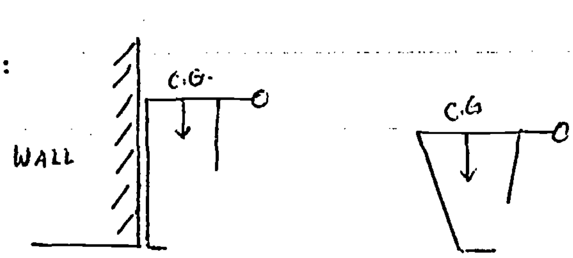
Demonstrate the determination of the center of gravity of an irregularly shaped metal plate (Physics Lab material) and how it can be balanced at the determined point.

Discuss how the weights of parts of a body can be considered as parallel forces directed toward the center of earth. Can these forces be combined into a resultant force? Where would it be located? Can the equilibrant at this point balance the body? Define center of gravity.

Have a student stand straight with his back to the wall and his feet at the baseboard. Ask him to bend and touch his toes (Be ready to stop him from falling)

Why can he not do it?

Show the position of his c.g. with respect to his feet with a diagram such as:



2. Centroid

Does an area have a center of gravity?

Balance a uniform rectangular plate horizontally.

Discuss the question of the c.g. being that of the area of the plate or the weight of the plate. Discuss what would happen to location of the c.g. if we concentrated a weight on one corner of the plate.

What do we mean by c.g. of an area and center of an area? If they coincide what is it called? Define centroid, or center of area of that material.

Show simple symmetrical areas and elicit answers as to the location of the centroid. Explain and show the use of the nomenclature $\bar{x}$ and $\bar{y}$ as co-ordinates of the centroid.

With class participation make up a table (with diagrams) of centroids of simple areas. Ref. 5-p. 162.

3. Moment of Area

Define and explain moment of area. Demonstrate, by using simple areas, how to calculate $My = A\bar{x}$ and $Mx = A\bar{y}$ with respect to differently located axes.

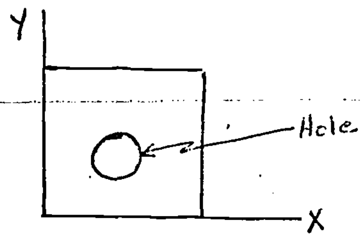
4. Centroid of Composite Areas

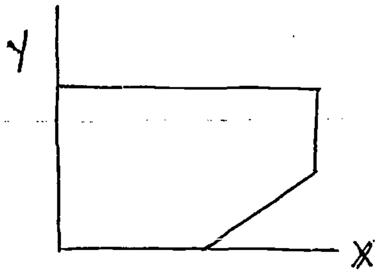
How do we find the centroid of a non-symmetrical area such as an angle section?

Demonstrate the method of using the principle of the moment of the entire area as equal to the sum of the moments of its component areas.

In determining the location of the centroid, show why it is advantageous to place the x axis through the lowest point of the composite area and the y axis through the left edge of the figure.

Show the handling of negative areas by treating figures such as:





Demonstrate the use of the x and y axis in symmetrical figures.

To simplify the handling of problems set up a format for the students to follow.

<u>Worksheet - Centroids</u>

1. What is the centroid of an area?

2. What does $\bar{x}$ represent?

3. When is it positive and when negative?

4. What does $\bar{y}$ represent?

5. When is it positive and when negative?

6. Where is the centroid of a right triangle?

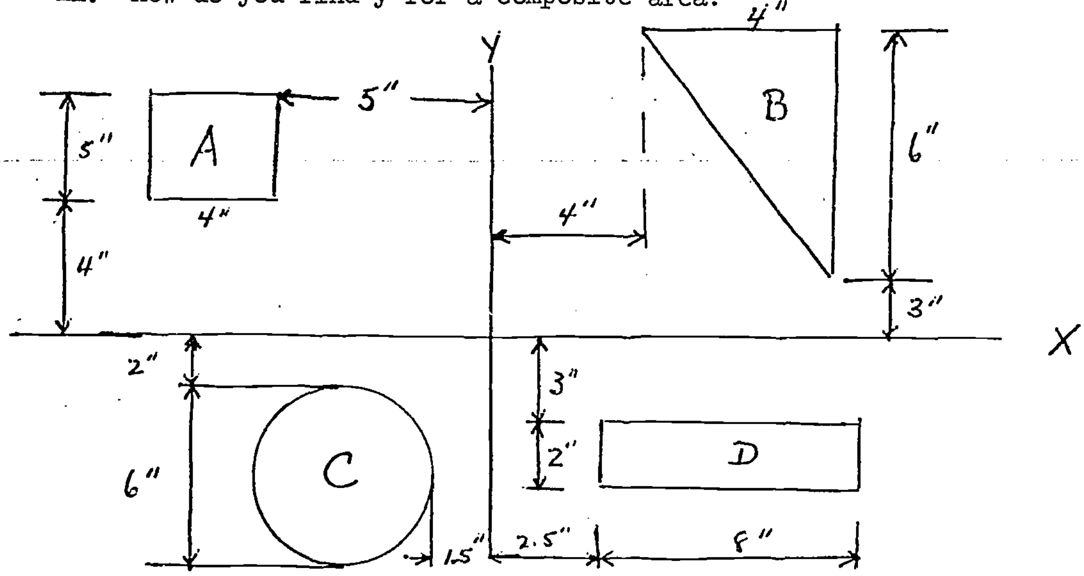
7. What is the moment of an area with respect to an axis?

8. What is a composite area?

9. How do you calculate the moment of a composite area with respect to an axis?

10. How do you find $\bar{x}$ for a composite area?

11. How do you find $\bar{y}$ for a composite area?



Locate the centroid of the following areas.

12. Rectangle A

13. Right Triangle B

14. Circle C

15. Rectangle D

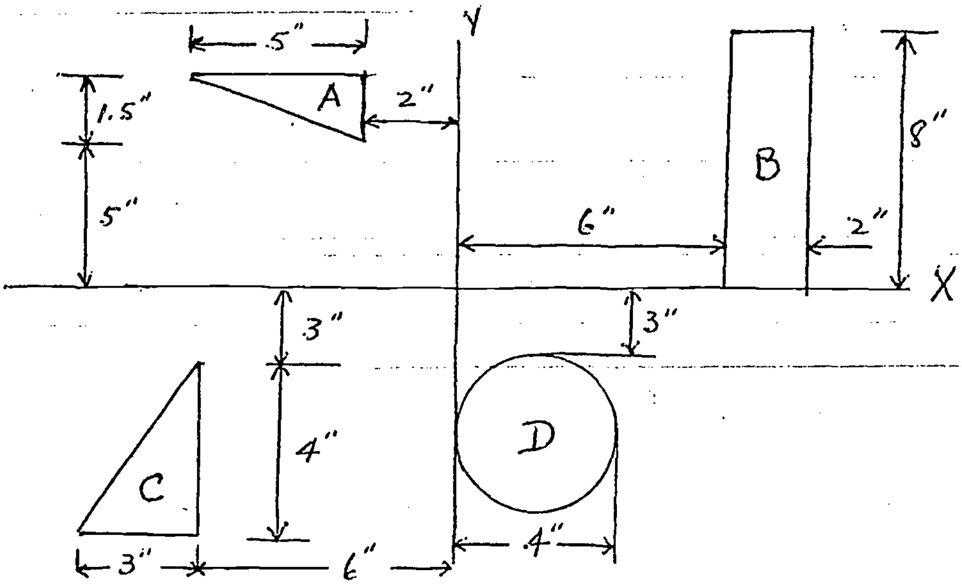
Find the moment of each of the following areas with respect to the x and y axes.

16. A

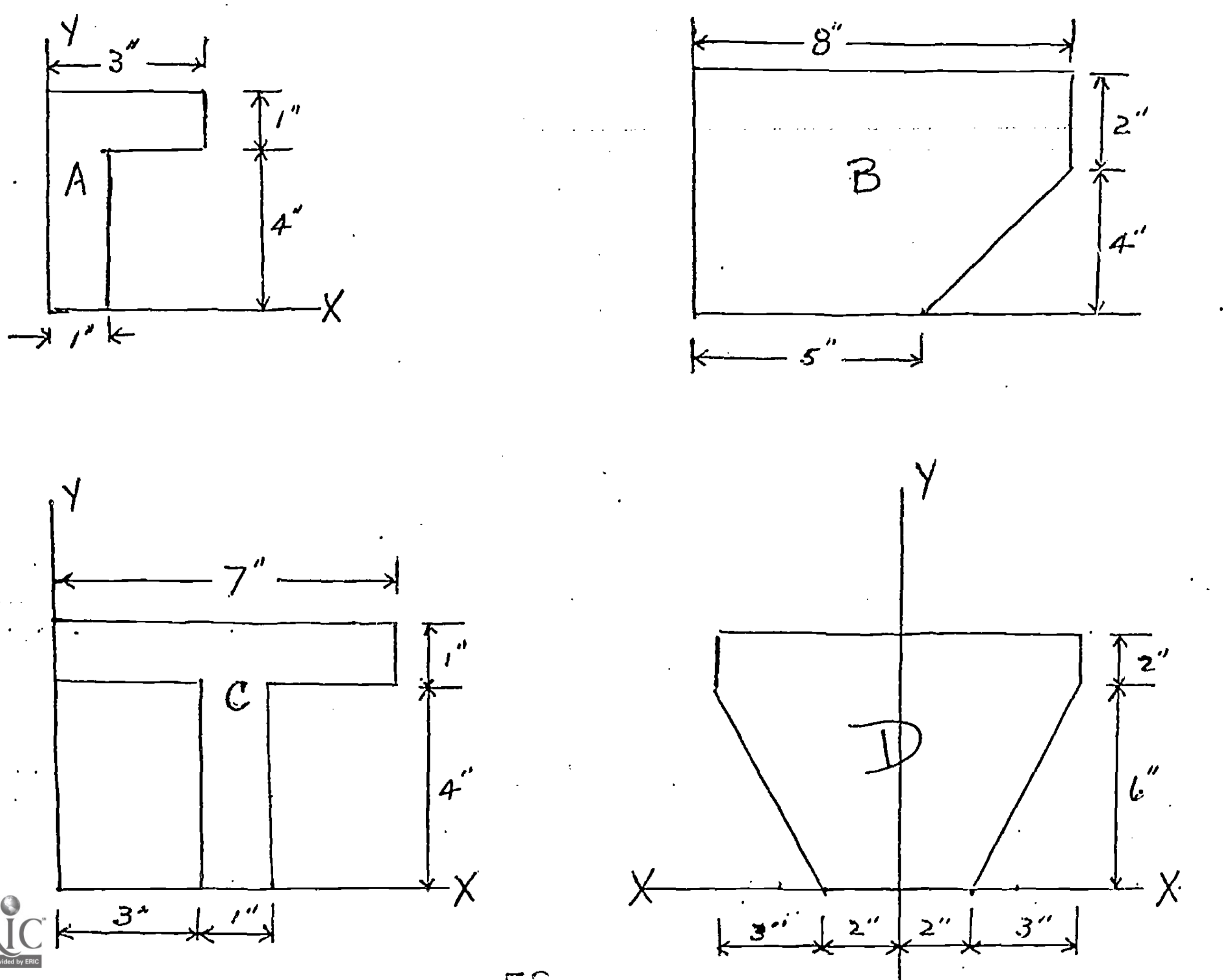
17. B

18. C

19. D



Calculate (a) the moment of the area in each of the following figures with respect to the x axis and with respect to the y axis (b) Locate the centroids.



20. Figure A

21. Figure B

22. Figure C

23. Figure D

Locate the centroid of the area in each of the following figures.

Remember negative areas and axes of symmetry.

FIGURE 1

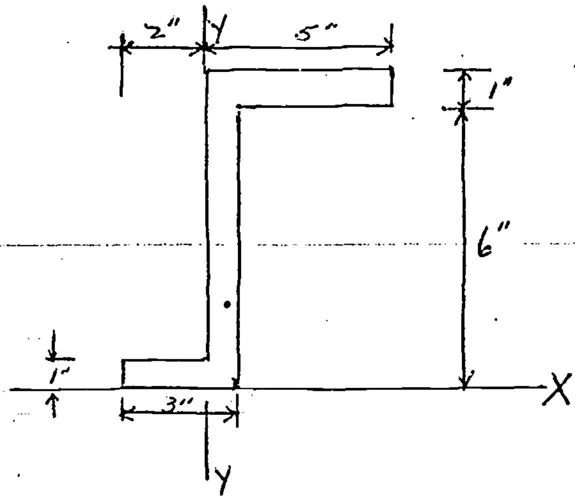
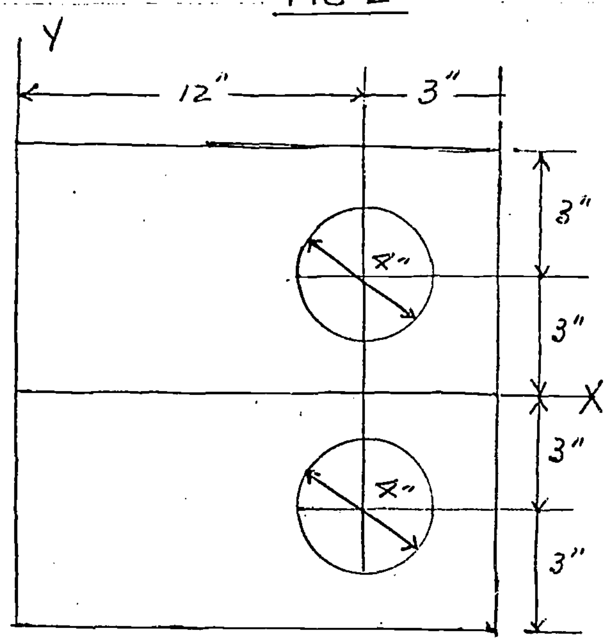


FIG 2



DIAM. of Holes 4"

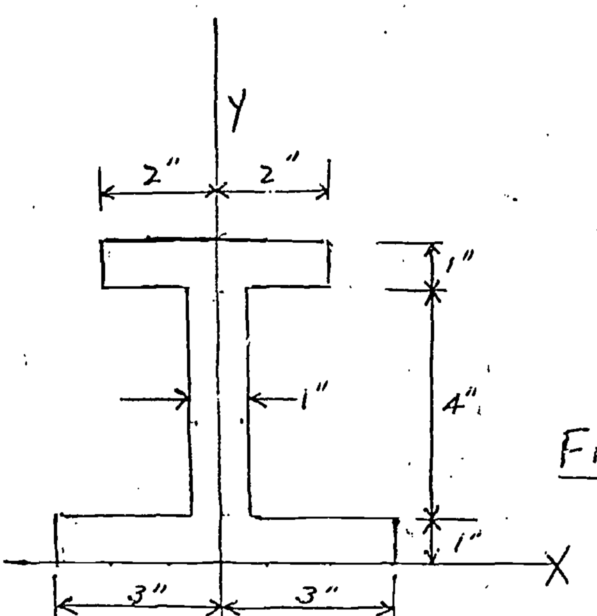


FIG. 3

24. Figure 1

25. Figure 2

26. Figure 3

5. Build-up Sections

Demonstrate the use of the AISC handbook to find the coordinates of the centroids of various sections.

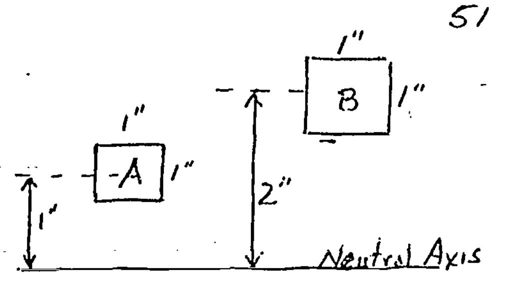
Put together, on the blackboard, a simple built-up section and show how the c.g. of the section is determined.

To develop facility in the handling of built up sections and the use of the steel tables, assign several simple built-up sections to be done in class.

VII. Moment of Inertia

Explain that in determining the strength of members which are loaded in bending, such as beams, a term appears in the strength equations which is called moment of inertia. It is necessary to have an understanding of the moment of inertia of an area before these members can be analyzed.

Explain the concept of the moment of Inertia (I) of an area about an axis as being the second moment of area, or the product of all the areas on both sides of the axis multiplied by the square of their distances from that axis.



Illustrate this by showing how I of area A is 1/4 that of area B and area B is 4 times as effective in resisting bending stresses.

How is the area of an I beam more efficiently distributed away from the neutral axis in order to resist bending stresses?

Make up a table of centroidal moments of inertia for simple areas for use in problems. Ref. 5 - p. 172

Using this table do several illustrative problems finding the moment of inertia of a rectangle about its y and x centroidal axes. About which axis is the moment of inertia greater? Discuss how the moment of inertia depends on the arrangement of the area with reference to the axis.

Show how the moment of inertia of a circle is the same about any centroidal axis.

Have the class find the moment of inertia about the centroidal axes of a right triangle.

LABORATORY ACTIVITIES

A Laboratory Manual for the Materials Testing Laboratory should be prepared, so designed, as to supplement the theory of Strength of Materials by illustrating its principles, provide training in the testing of materials, and the use of testing equipment.

The outline that follows, lists some of the suggested material to be incorporated in such a manual. The detailing of the subject matter suggested will depend upon the equipment available at the school. The instructional materials for operating equipment and performing tests should conform to the type and capacity of testing equipment available, however standard tests should conform to the general recommended procedures.

The students should be oriented in operating the machines before performing tests by attending several laboratory sessions devoted to studying the information and description sheets suggested in the outline and the experiment sheet devoted to "Inspection of Machines."

Laboratory experiments within the scope of the course should require a minimum of two periods (80 minutes) for completion. Less time than this would be insuffieient to properly perform the experiments.

The outline suggests material, which when prepared, should provide a means of developing skills for observing, presenting, and interpreting test data as well as skills in writing technical summaries and reports.

LABORATORY ACTIVITIES - OUTLINE

1. Introduction Sheets.

    a) Description of the objectives of the materials testing laboratory.

    b) General description of material tests.

    c) Instructions for Lab procedure

    d) Instructions for Lab Reports

2. Information Sheets - Testing Machines

    a) Description and operating procedures for testing equipment and mechanisms

3. Formalized experiment sheet for the purpose of study, observation and to become familiar with the various types of equipment and their safe and proper operation. Supply data sheet and series of questions.

4. Information Sheets - preparations for individual experiments.

    a) On tension tests for metals (steel, brass, etc.)

    b) On tension tests for wire or cable

    c) Tension tests for sheet metal, riveted and welded joints, spot welds, fabric, plastic

    d) Compression tests of wood

    e) Transverse bending

5. Demons·ration Experiment for Tensile Test of Steel. Format to follow during demonstration: Include object, equipment, material, theory, procedure, data (observed and calculated), graph procedure, conclusions and analysis.

6. Test or experiment sheets for following tests: (to include references, object of test, equipment, procedure, data (observed and calculated), results, and questions.)

a) Vectors - Force board, Boom, etc.

b) Equilibrum - moments and parallel forces

c) Hooke's Law

d) Coefficient of linear expansion

e) Inspection of machines

f) Tension - steel, aluuminum, brass, fabric, cement and mortar, rivets, sheet metal, wire, plastic

g) Compression - wood, metal, brick, concrete

h) Transverse bending

i) Torsion

j) Hardness

k) Impact

l) Verification of Equipment

m) Shear - bolts or rivets, welds, spotwelds

The students should have no trouble finding the moment of inertia about the x centroidal axis but there will be many questions about finding Iy.

This affords the instructor an excellent opportunity to show that the term b in $I = \frac{bh^3}{36}$ is the dimension parallel to the axis about which the moment of inertia is being taken, while h is the dimension perpendicular to the axis.

Question the class as to how this information can be used to find Iy. Complete the problem

Worksheet - Moment of Inertia

1. Define the moment of Inertia of an area.

2. Find the moment of inertia about the centroidal axes of a rectangle with a vertical dimension of 10" and a horizontal dimension of 6".

    a) What is the formula for Ix for a rectangle?

    b) The factors b and h in the formula are dimensions parallel to which axes?

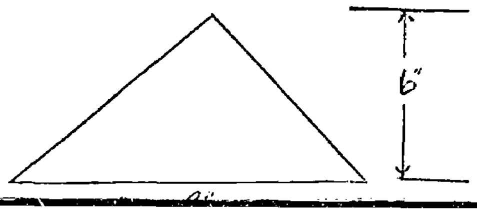
    c) Find Ix and Iy

    d) Are they equal?

    e) In what units is moment of inertia expressed?

    f) Do these units have any physical significance?

3. Find Ix with reference to the horizontal centroidal axis of the triangle shown.



4. Calculate the moment of inertia of a circular area, 2" in diameter with respect to the y and x axes through the center .

    a) Are they equal?

5. Calculate I_x and I_y about the centroidal axes of a right triangle with a base of 3" and a height of 6".

On the blackboard show the rectangular section of a beam as 6" x 8". Next to it show another section 4" x 12".

1. Comparison of I

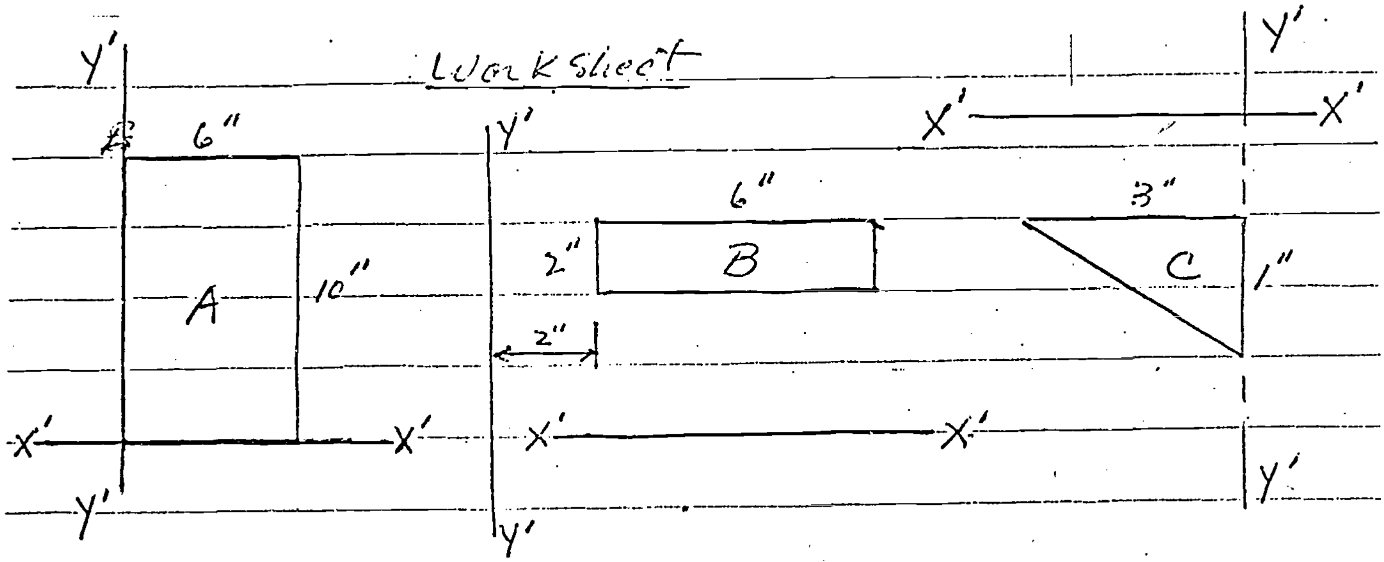
Are the cross sectional areas equal? Which has the greater moment of inertia about its horizontal centroidal axis? Calculate the I_x for both sections. Which section has a greater ability to resist rotation about its centroidal axis? To resist a bending load?

2. Transfer Formula

Show several simple sections of a beam on the blackboard, such as a rectangle, circle, triangle. Explain how it is often desirable to obtain the moment of inertia about some other axis which is parallel to the centroidal axis. Demonstrate how this is accomplished by $I_{x1} = I_x + Ad^2$

Have the class do some drill problems along this procedure.

Worksheet



1. Find for figure A the moment of inertia about the $x^1 - x^1$ and $y^1 - y^1$ axes.

2. Do the same for figure B

3. Do the same for figure C

3. Composite Areas

Explain why it is important to know how to determine the moments of inertia of composite areas since many structural members such as beams, columns, and built up sections are composed of such areas. On the board show sample sections of such areas.

Demonstrate the steps of calculation with a simple T section. Emphasize the step by step procedure and summarize the steps:

1. Divide the area into simple areas

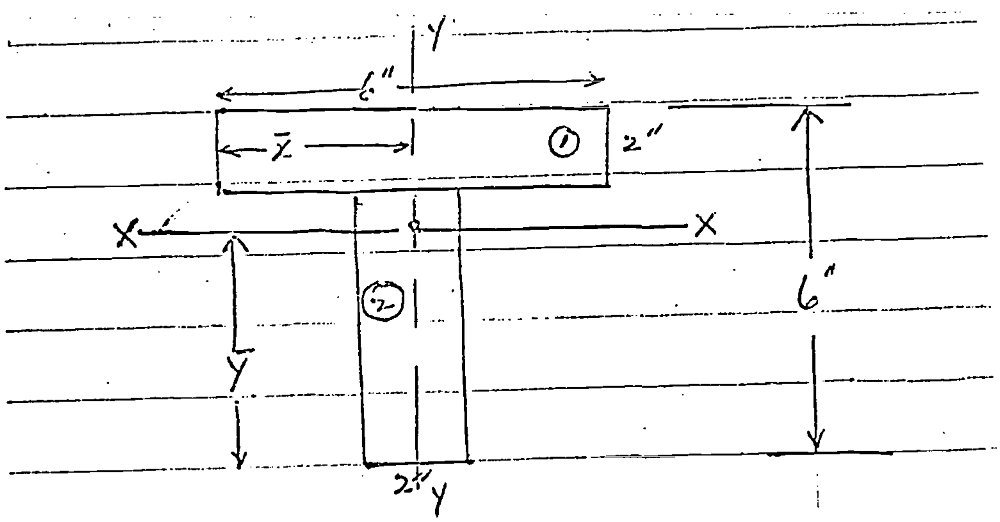
2. Locate the centroid of each area

3. Calculate the moment of inertia about the centroid axis (gravity axis)

4. Transfer the I_g to the parallel axis

5. Add the moments of inertia of the parts of the area about the new axis to get the moment of inertia of the entire area.

For class participation set up another T section as:



What simple areas can the T section be broken into (1 and 2)

Where is the vertical centroid axis located?

Is the area symmetrical? What is $\bar{x}$? (3")

How do you find $\bar{y}$, the location of the x centroid axis?

$$(\bar{y} = \frac{\Sigma Ay}{\Sigma A}) = \frac{(12)\ (5)\ +\ (8)(2)}{12 + 8} = 3.80''$$

At this point explain the significance of the coordinates $\bar{x}$ and $\bar{y}$.

To facilitate the procedure that follows set up a table such as:

For I_x - Taking moments about Axis XX

Area (Member)	I	A	d	d^2	Ad^2	$I + Ad^2$
1 6"x2"	4	12	1.2	1.44	17.28	21.28
2 2"x4"	10.67	8	1.8	3.24	25.92	36.59
						$I_x = 57.87$ in.^{4}
For I_y						
1	36	12	0	0	0	36
2	2.67	8	0	0	0	2.67
						$I_y = 38.67$ in.^{4}

Have the class calculate and fill in the values of the table.

Point out that in this case the vertical gravity axix of the entire figure coincides with the vertical centroidal axis of each rectangle. What is the transfer distance, d.?

Worksheet

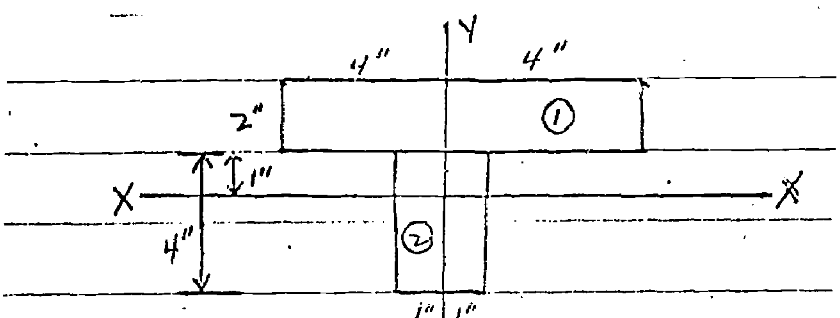


Figure 1.

1. Calculate the moment of inertia of the entire area of the figure about the y and x axes shown. (Figure 1)

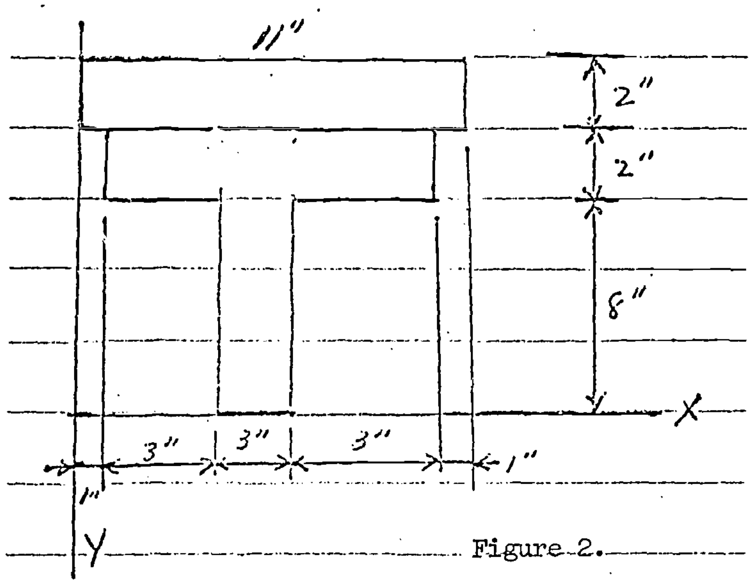


Figure 2.

2. Find the coordinates of the centroid of the built-up section shown in Figure 2.

3. Find the centroidal moment of inertia of the sectional area about the horizontal centroidal axis of Figure 2.

4. Calculate the moment of inertia of the area shown in Figure 3 with respect to the (a) x axis

(b) y axis

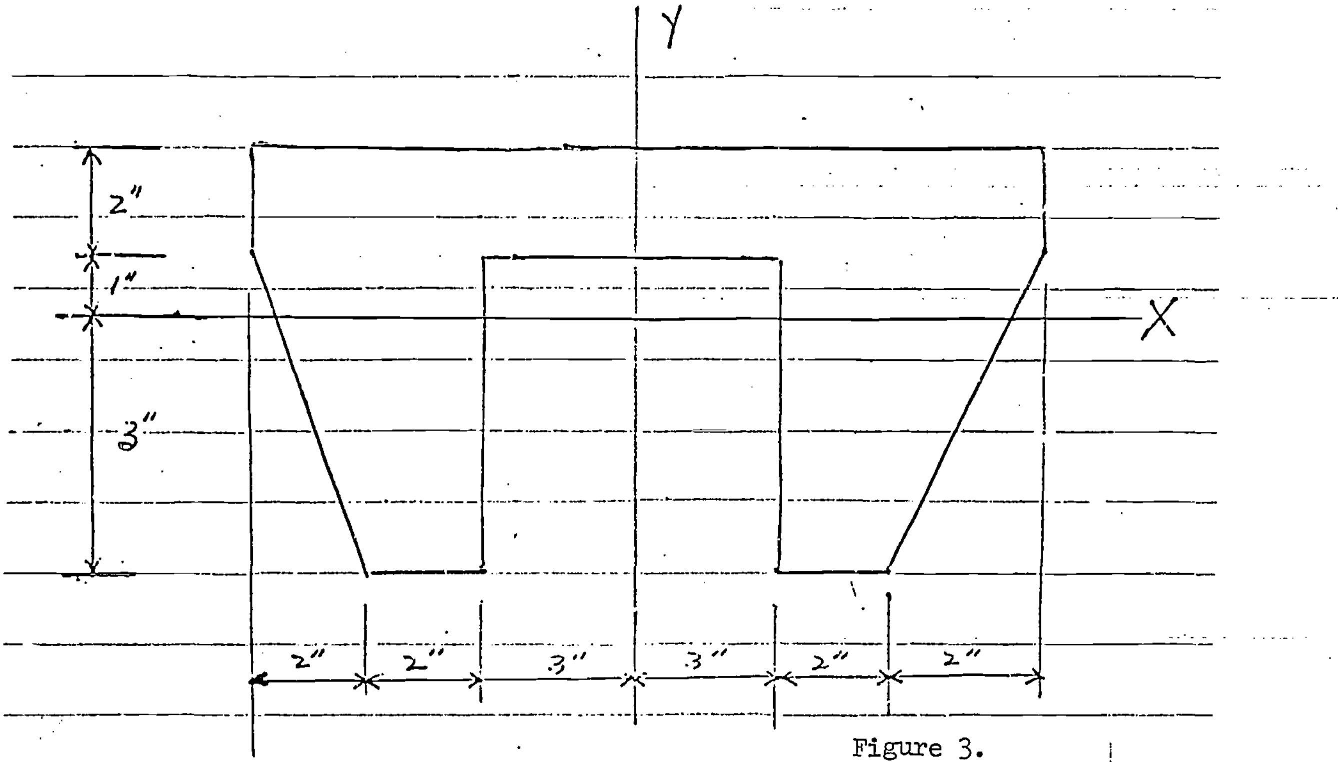


Figure 3.

4. Beams of Standard Section

What are Standard Sections? What types are there? What are rolled sections? Discuss with the class the use of the tables of the Standard Sections. Explain the nomenclature as used in the tables, the dimensions, the centroid axis, the significant properties such as area of cross section, the moment of inertia, and the standard designation of a section such as 10 WF 23.

To illustrate the use of the tables, with class participation, do a sample problem on the blackboard as finding the moment of inertia

about the x axis of a built-up section consisting of 2 flange plates 2" x 12", 4 angles 5" x 5" x $\frac{1}{2}$" and a web plate 1" x 16". (Ref. 2 - p. 125, Probl.)

VIII Flexure Formula

Explain the beam theory and show how the fiber stresses over any cross section of a beam are at a maximum at the entrance outer fibers and decrease to zero at the neutral axis. Use a simple rectangular cross section as a model.

Ref. 5 - p. 184: Ref. 1 - p. 65

Derive the formula $S = \frac{Mc}{I}$ from the basic concept that the internal resisting moment of a beam must be equal to the maximum bending moment.

Emphasize that S is the maximum fiber stress due to bending in psi. and M is the bending moment in in.-lb and not lb-ft. Explain that the ratio I/c is called the section modulus and how it is read from the tables for standard sections. Emphasize that the equation for stress due to bending applies only within the elastic range of the material, since the proportionality of stress and strain was used in its derivation.

With an illustrative problem, using a beam of rectangular cross section, go through the full procedure for calculating the maximum bending stress. With the class participating in the developing procedure, have them note the step by step procedure:

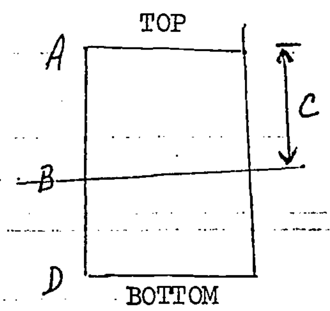
1. Draw the free body diagram
2. Find the reactions
3. Locate the point where the shearing force is zero.
4. Calculate the maximum bending moment (where the shear force is zero). Be sure that the class notes that the bending moment is in lb-in.
5. Locate the neutral axis of the cross section
6. Determine the distance, c.
7. Calculate the moment of inertia of the area of the cross section with respect to the neutral axis.
8. Apply the flexure formula, $S = \frac{Mc}{I}$

Worksheet - Flexure Formula

1. A load produces a bending in a beam at all points. The upper fibres are in ____________ (compression, tension) and the lower ones are in ____________(compression, tension).

2. There is no stress along the _______ axis of a section of a beam.

3. If the figure is the cross section of a beam under a transverse load



a) Where is the neutral axis?

b) Where is the bending stress zero:

c) Where is the maximum compressive stress?

d) Where is the maximum tensile stress?

e) How do the compressive and tensile stresses vary with the distance from the neutral axis?

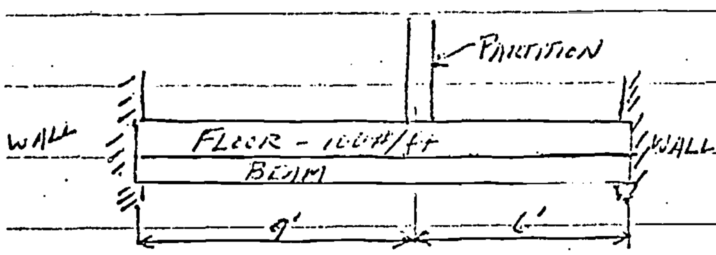
f) Draw a diagram showing this variation.

4. What is the formula for bending stress?

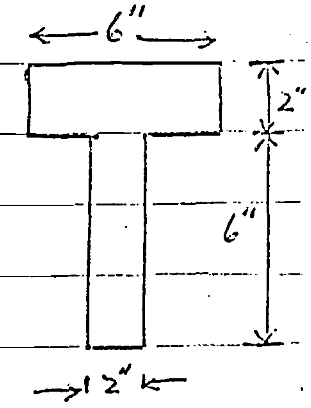
5. In what units should the bending moment be expressed when you calculate bending stress?

6. A beam of rectangular cross section, 6" x 10" is subjected to a bending moment of 9200 lb.ft. Calculate the maximum bending stress.

7.



Beam in place



Cross Section

The beam shown supports a floor and partition. The floor exerts a uniformly distributed load of 100 lbs. per ft. on the beam. The partition exerts a concentrated load of 600 lbs. The beam is supported by the walls at the ends. The cross section of the beam is shown as a T.

a) Draw the free body diagram

b) Find the reactions.

c) Draw the shear diagram

d) Where is the zero shearing force? the maximum bending moment?

e) Change the maximum bending moment to lb.in.

f) Find the neutral axis

g) Find the distance from the neutral axis to the bottom and to the top of the section.

h) Calculate the moment of inertia of the section with respect to the neutral axis.

i) Calculate the maximum bending stress.

a) Wood Sections

Discuss the use of timber as structural members. Show the class a table of American Standard sizes for timber. Note the information supplied such as dressed size, area of section, moment of inertia, and section modulus.

Using a rectangular section of a wood beam, with b as base and h as height, derive the flexure formula $\frac{M}{s} = \frac{I}{c} = \frac{bh^2}{6}$ for a rectangular wood section.

Exphasize that the section modulus, $\frac{bh^2}{6}$, is a measure of strength of the beam.

To illustrate this, show the difference in maximum bending stress in a 8" x 10" beam and a 10" x 8" beam. Explain dressed or actual size dimensions.

Show the class a table of working stresses for principal species of wood used for structural work.

By using these tables, show the class how a beam can be selected for use by finding the appropriate b and h.

<u>Example</u>: Find b and h for a white Fiv beam with a maximum bending moment of 8940 lbs.

Worksheet - Wood Sections

1. How big is a 10" x 14" in actual size?
2. What is the area of cross section of 2 x 8?
3. Find I_x for a 4 x 12.
4. What is the section modulus with respect to the y axis for 6 x 10?

5. Which wood section in the table has an area closet to 35 sq. in.?

6. Pick out a wood section for which Iy is equal to 104 in.^{4}

7. What is the flexure formula for rectangular wood section? The section modulus?

8. Design a rectangualr wood beam (find b and h and select the commercial size of the beam) whose maximum bending moment is 11,200 ft. lbs. The beam is Southern Yellow Pine.

b) Use of Tables

Discuss the problems involved in deciding (designing) what beam to use: wood or steel, size that is strong enough for the load, shape of steel section.

Explain how these problems can be handled by reference to tables of properties of various types of sections and why it is important to learn how to use these tables.

Referring to tables of various sections, explain the shape of the member, dimensions, and nomenclature.

Drill in the use of the table to promote familiarity.

Worksheet - Tables

1. What does 12 WF 58 mean?

2. For a 16 WF 40 section what is the web thickness, I_x, Z_x?

3. Select a wide flange section that has a Z_x of 24.1

4. For a 12 WF 45, what is I_x?

5. Find the area of cross section of a 14WF 68.

6. What is the meaning of 15 I 50?

7. What is Z_x for a 6 I 12.5?

8. What is the meaning of $\angle$ 6 x 6 x $\frac{1}{2}$?

9. How much does the angle 4 x 4 x $\frac{11}{16}$ weigh?

10. Find I_x for an angle 3 x 3 x $\frac{5}{16}$

11. Locate the centroid of the angle 5 x 5 x $\frac{3}{4}$

12. Pick out the angle for which Z = 1.7

13. What is the area of cross section of angle 7 x 4 x $\frac{3}{8}$?

14. Find I_y for angle 4 x 3 x $\frac{1}{4}$

15. What is Z_x for angle 6 x 3 x $\frac{1}{2}$?

16. For which unequal angle is I_y equal to 10.5?

17. A 10 WF 23 is loaded so the loads are perpendicular to the x axis. The maximum bending moment is 19,400 lb. ft. Calculate the maximum bending stress.

   (a) What is M in lb. in.?

   (b) From table, what is Z_x?

   (c) Calculate the maximum bending stress.

18. A 2 x 12 wood joist, 16' long, is placed with the larger dimension vertical and is supported at the ends. The joist is subjected to a uniformly distributed load of 80 lb. per ft. Calculate the maximum bending stress.

    (a) Draw the free-body diagram.

    (b) Find the reactions.

    (c) Draw the shear diagram.

    (d) Locate where the shearing force is zero.

    (e) Locate where the maximum bending moment occurs.

    (f) Convert the maximum M to lb. in.

    (g) From table, find Z_x.

    (h) Calculate the maximum bending stress.

c) Selection of Beam
Ref. 1 - p. 78
Ref. 2 - p. 158

Explain how the problem of designing a beam of standard section is a matter of selecting the the type and size of beam for the load. Discuss factors other than strength of materials to be considered such as economy and fastening the beam.

Illustrate the selection of a beam by use of the flexure formula in the form of $Z = \frac{M}{s}$.

Example: Pick out a suitable American Standard Steel I beam to carry a maximum bending moment of 32,800 lb. ft. with a working stress of 18,000 psi.

Have the students calculate the section modulus Z. (21.8 in.^3)

Let them select from the tables the figure 24.4 which is close to and larger than 21.8. Their selection should be 10I25.4

In order to minimize the mathematical load on the students, demonstrate the derivation and use of the general formulae for maximum bending moment on - for example, a simple beam with a concentrated and a uniform load. Thus the use of $M = \frac{PL}{4}$ and $M = \frac{WL}{8}$ can save time and energy in arriving at the outcome of a design problem.

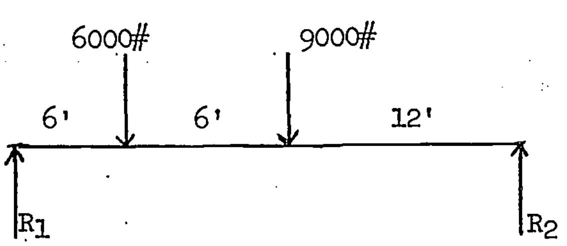
Show the use of these relationships in an illustrative problem.

(Ref. 2 - p. 158)

Worksheet - Selection of Beam

1. A wood joist 16' long is to be supported at the ends. The joist is to carry a uniformly distributed load of 60 #/ft. over the entire length, and a concentrated load of 200 lbs. at a point 6' from the left end. The working stress is 1200 psi. What size of joist should be used?

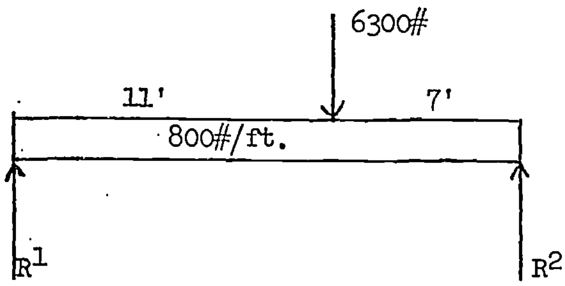
2.



Select a wide-flange beam to carry the loads shown in the figure.

The working stress is 16,00 psi.

3. An American Standard beam is to carry the loads shown in the following figure with a working stress of 20,000 psi. Select the beam.



4. A cantilever beam carries a uniform load of 400 lb. per ft. across the entire 9' length of span and a concentrated load of 3000 lb. at the free end. For a maximum allowable stress of 20,000 psi determine the most economical beam (lightest beam that satisfies the strength requirement), assuming that the section is:

(a) A WF beam

(b) A standard I beam

(c) A standard channel

(Note: Maximum bending moment $M = \frac{WL}{2}$ for a cantilever beam of uniform load and M = PL for the concentrated load.)

IX Shear Stress Ref. 5- p. 218

Describe the physical action of horizontal shear by the movement of several flat boards of equal length with respect to each other as they are loaded at the center of the pile (Ref. 5-p. 218). How is this lateral sliding movement prevented if the boards are bolted together? if the pile of boards are replaced by a single beam?

Define the horizontal shearing strength as the resistance of the fibers to the sliding motion. Demonstrate how $S_h = \frac{Va\bar{y}}{Ib}$ (See Ref. 2 - p. 221)

Analyze the sample problem of Ref. 2 - p. 222. How does Sh vary with V?

Where will maximum Sh occur?

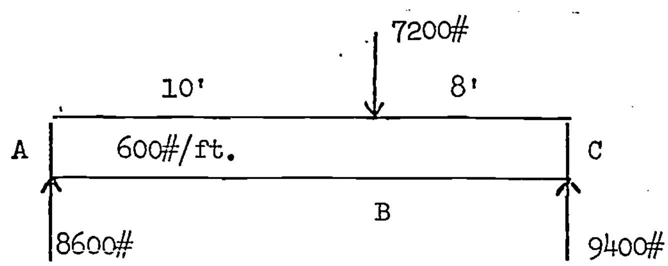
Show that the distribution of horizontal shearing stresses for for the rectangular section forms a parabola with Sh at a maximum at the neutral axis and zero at the outer fibers.

Illustrate the use of the special case of horizontal shear stress at the neutral axis of a rectangular cross section as $S_h = \frac{3V}{2bh}$

Show the use of vertical shear stress (as equal to the horizontal) in the case of standard steel sections as $S = \frac{V}{A}$

Worksheet - Shear Stress

1.



The figure shows the free body diagram of a 12WF45 beam.

Calculate the maximum shearing stress.

(a) Draw the shear diagram.

(b) Where is the maximum shear?

(c) Find the area of the web (Find the depth and thickness of web from tables)

(d) Find the maximum shearing stress.

2. A 4 x 10 wood beam is subjected to a maximum shearing force of 3160 lbs. Calculate the maximum shearing stress.

(a) What is the area of section? (See tables)

(b) Calculate the maximum shearing stress.

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