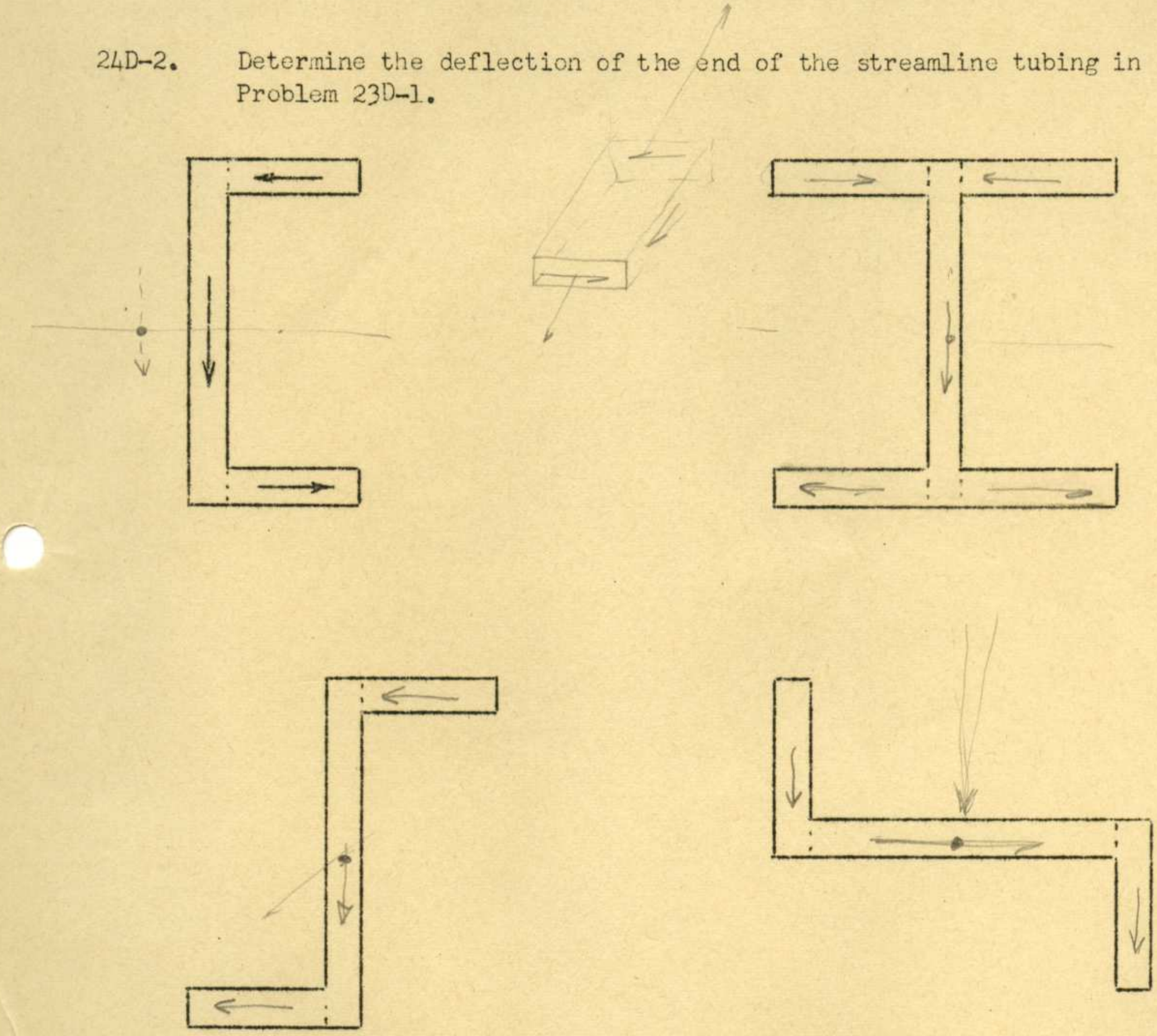
BM 9/11/43

MECHANICS OF MATERIALS PROBLEMS CURTISS-WRIGHT ENGINEERING
Course B-4 Seely: Art. 132-135 CADETTES 24D-A-137

24D-1. Each of the sections in Fig. 24D-1 represents the cross section of a cantilever beam carrying a vertical concentrated load through the shear center at the free end. Indicate the direction of the shearing force, if any, developed parallel to the long side in each rectangle of the section, as illustrated for the channel.

24D-2. Determine the deflection of the end of the streamline tubing in Problem 23D-1.



TYPICAL SECTIONS A-A

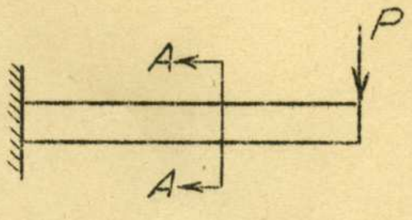


FIG. 24D-1

MECHANICS OF MATERIALS | REVIEW PROBLEMS | CURTISS-WRIGHT ENGINEERING
Course B-4 | Seely | CADETTES- 32DO-A-149

32DO-1. Construct shear and moment diagrams for the beam loaded as shown in Fig. 32DO-1.

32DO-2. A 50-in. diameter boiler is made of steel plate ½ in. in thickness. The boiler is subjected to an internal pressure of 110 p.s.i. The longitudinal seam is a double riveted butt joint with a single 9/16-in. splice plate. The outside rows of rivets have a pitch of 6 in. and the inner rows a pitch of 3 in. The rivets are 7/8 in. in diameter. Determine the average shearing and bearing unit stresses, and also the average tensile unit stresses at both net sections of the main plate.

32DO-3. A cantilever beam has a cross-section as shown in Fig. 32DO-3. The beam is 8-ft. long and has a concentrated load of 600 lb. acting along the x-x axis at the free end.

(a) Determine the maximum fiber stress in the beam.

(b) Determine the maximum deflection in the beam.

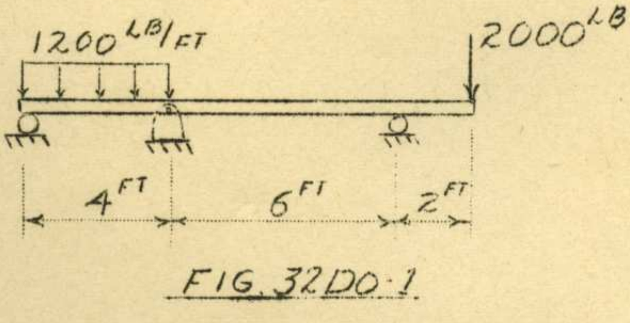


FIG. 32DO-1

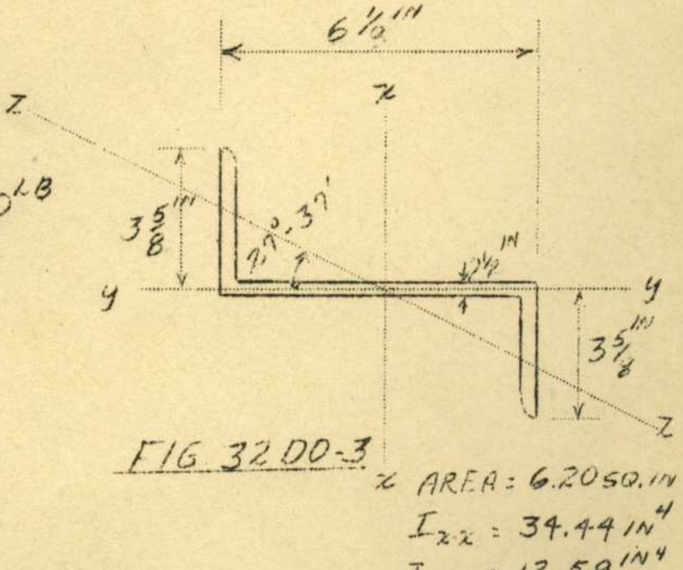


FIG. 32DO-3

AREA = 6.20 SQ. IN

$I_{x-x} = 34.44\ IN^4$

$I_{y-y} = 12.58\ IN^4$

$I_{z-z} = 4.36\ IN^4$

32DO-4. Determine the shearing stress on the rivet which carries the greatest load in the connection indicated in Fig. 32DO-4. All rivets are 5/16 in. in diameter and are in single shear.

32DO-5. An airplane engine develops 1400 h.p. and is turning over at the rate of 1800 r.p.m. The hollow drive shaft has an outside diameter of 4 in. and an inside diameter of 3 in. The propeller has an efficiency of 80%. If the airplane is traveling in horizontal, level, steady flight at 240 m.p.h. determine the normal and shearing unit stresses in the propeller shaft at the end of a horizontal diameter on a plane that makes an angle of 30° with the horizontal.

32DO-6. Member DG in the truss shown in Fig. 32DO-6 (a) is a $1\frac{1}{2}$ by $1\frac{1}{4}$ by $\frac{1}{4}$-in. 1025 steel angle, the properties of which are indicated in Fig. 32DO-6 (b). The effective length of the member is 46 in. and the fixity factor may be assumed to be 2.0. The $1\frac{1}{2}$-in. leg is to be welded to a gusset plate at each end. Design a welded connection which will develop the full strength of the member when DG is in compression. Refer to ANC-5 for allowable loads on welded seams.

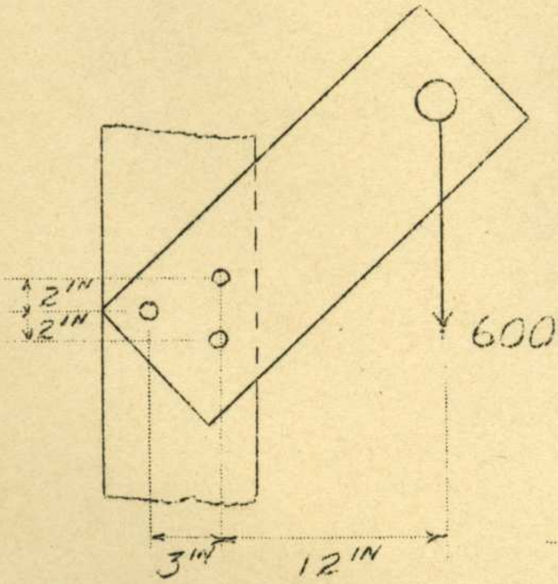


FIG 32DO-4

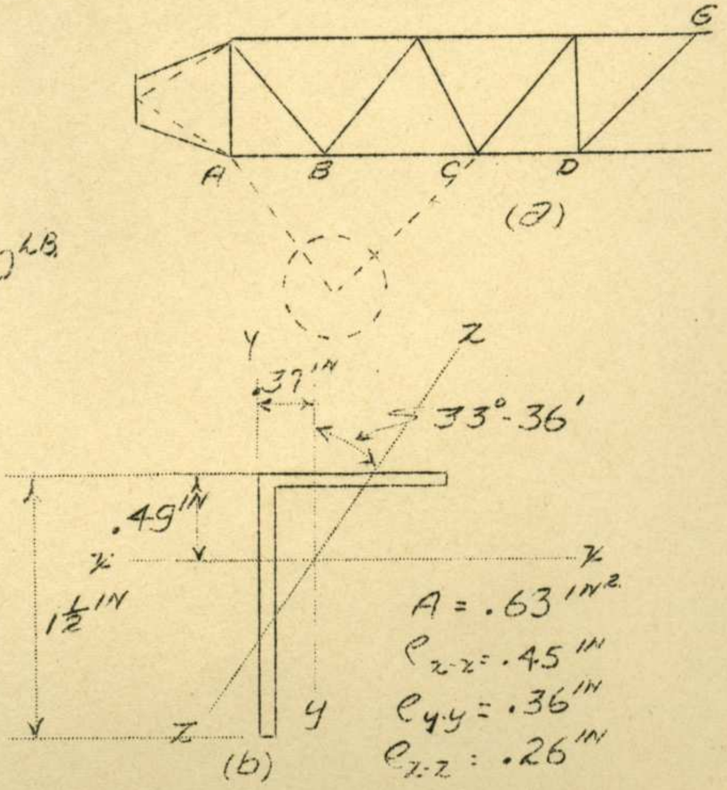


FIG 32DO-6

MECHANICS OF MATERIALS	FINAL EXAMINATION (10432)	CURTISS-WRIGHT ENGINEERING
Course B-4	Seely	CADETTES 33D-G-150

Note: Show all work, including scratch work in blue book. Original questions need not be copied in blue book.

1. (a) The proportional limit of a material is defined as ________________
   (b) Define the coefficient of thermal expansion.
   (c) Define modulus of rupture as applied to a beam.
   (d) Give a reasonable value for the modulus of elasticity of Douglas fir or white pine.
   (e) Define shear center.
   (f) What is a principal axis?
   (g) Draw the conjugate beams for the beams shown in Fig. 1 (g) showing end conditions only (no $\frac{M}{EI}$ loads).
   (h) Figure 1 (h) indicates a shaft coupling. What is the relationship between the unit shearing stresses in the bolts in the two bolt circles?
   (i) The direction of the neutral axis of the cross section of a beam subjected to unsymmetrical bending is dependent upon three factors. Name them.
   (j) Give the formula for evaluating the unit shearing stress in a beam. Define, explain, or illustrate the significance of each term.

2. A hollow steel propeller shaft with an outside diameter of $3\frac{1}{2}$ in. and a $\frac{1}{4}$-in. wall thickness transmits a torque of 4,000 Ft. lbs. The shaft is 5 ft. long, $E = 30(10)^6$ p.s.i. and $G = 12(10)^6$ p.s.i. Determine

   (a) The maximum unit shearing stress.

   (b) The magnitude of the angle of twist in radians.

3. (a) Draw the shear and moment diagrams for the beam shown in Fig. 3 (a).
   (b) If the beam has a cross section as shown in Fig. 3 (b) determine the maximum fiber unit stress.

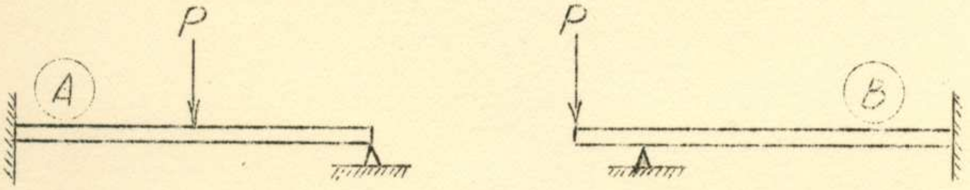


FIG 1 (g)

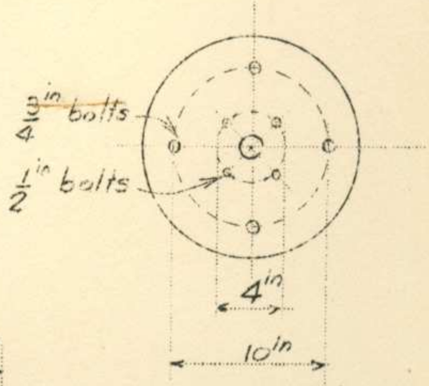


FIG. 1 (h)

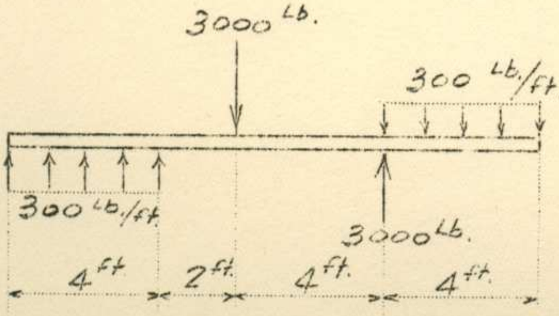


FIG. 3 (a)

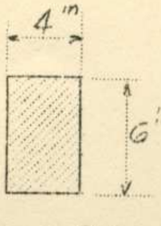
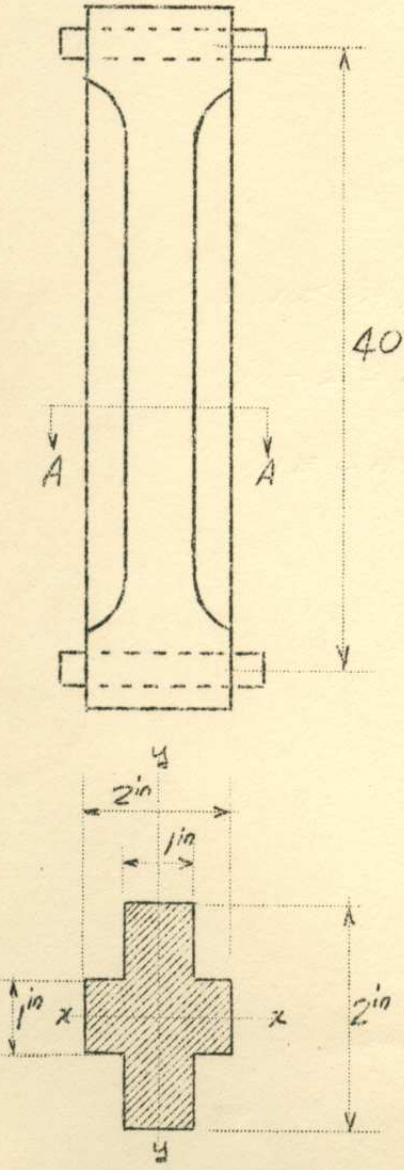


FIG 3 (b)

4. Two .081-in. 17S-T aluminum alloy sheets are connected by means of a triple riveted lap joint, a portion of which is shown in Fig. 4. The rivets are $\frac{1}{4}$ in. in diameter and the allowable stresses are $F_t = 55{,}000$ p.s.i., $F_s = 30{,}000$ p.s.i. and $F_{br} = 75{,}000$ p.s.i.
   (a) Determine the efficiency of the joint.
   (b) Determine the maximum allowable load per repeating group of rivets which the joint will carry with a margin of safety of .15.

5. A 24S-T forging to be used as a column is shown in Fig. 5. The fixity factor with respect to the x-x axis is 1, and with respect to the y-y axis is 2. The critical $\frac{L'}{\rho}$ is 79.2, $F_{co} = 50{,}000$ p.s.i., $K = 421$ p.s.i., $n = 1$, and $E = 10{,}500{,}000$ p.s.i. Determine the maximum axial load the column may be expected to carry.

6. The member shown in Fig. 6 has a solid circular cross section of radius r. Determine the minimum permissible radius of the member if the maximum tensile stress on Section A-A shall not exceed 20,000 p.s.i.



SECTION A-A

FIG. 5

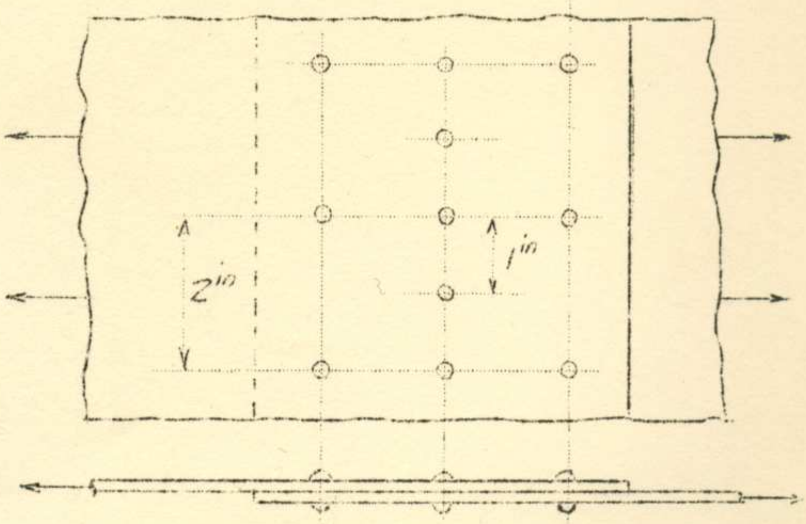


FIG. 4

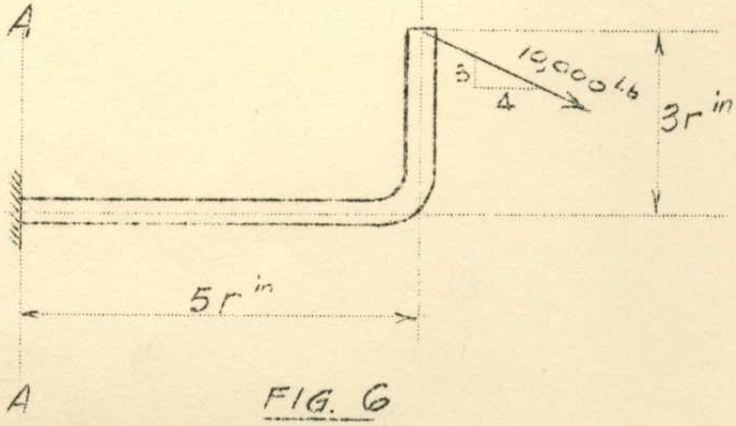


FIG. 6

10/19/43
from G.M.

MECHANICS OF MATERIALS — ASSIGNMENT SHEET — CURTISS-WRIGHT ENGINEERING
Course B-4 — Seely : Resistance of Materials, 2nd Ed. — CADETTES — 1D-G-105

Week No.	Beginning	Period No.	Topics	Advance Articles	Assignment Problems
1	7-20	1	Stresses under central loads	1-5	7, 14, 17
		2	Stresses on oblique sections, strains	6-7; 9-10	22, 35, 43
		3	Stress-strain relationships, working stress, factor of safety, specifications, thermal stresses	12-14	62, 65
2	7-27	4	Thin-walled cylinders and spheres under internal pressure	15-18	70, 73
		5	Riveted joints under axial loading	19	84, 85
		6	Welded joints under axial loading	20-22	96, 97
3	8-3	7	Torsional stresses in solid and hollow circular shafts	23-24; 26	113, 117
		8	Distortion of solid and hollow circular shafts in torsion	27-28	122, 123
		9	Tension and compression in torsional members	1-28	58, 72, 100, 132
4	8-10	10	Review		
		11	Quiz	29-31	135, 141, 145
		12	Flexure formula	33	156, 176
5	8-17	13	Shear and moment diagrams	35-37	169, 186
		14	Shear and moment diagrams	38-39; 41	189, 190
		15	Shearing stresses in beams	116-117	214, 217
6	8-24	16	Review		
		17	Deflection of beams	118-121	227, 431
		18	Deflection of beams	128-130	243, 245
7	8-31	19	Fixed beams	131; 58	254, 255
		20	Theorem of three moments		
		21	Review		
8	9-7	22	Quiz		

1D-1. An airplane is towing a cargo glider in horizontal level flight with an acceleration of 5 ft. per sec.^{2} forward. The weight of the glider is 8000 lb., and the total drag on the glider is 500 lb.
Determine the required area for the towing cable if the stress in the cable is not to exceed 1,200 p.s.i.

1D-2. The control stick shown in Fig. 1D-2 weighs 4 lb. and is subjected to a force of 100 lb. as shown.
(a) Determine the unit tensile stress in the 1/8 in. cable.
(b) Determine the shearing stress in the pin if the pin is 1/4 in. in diameter.

1D-3. The turn buckles Q and R on the King Post truss shown in Fig. 1D-3 are tightened until the compression member EB exerts a pressure of 25,000 lb. on the beam ABC. Member BE is a hollow shaft with an inner diameter of 1 in. and an outer diameter of 2 in. Rods AE and EC each have a cross sectional area of 2 sq.in. The pin at A has a diameter of 1.25 in. Determine
(a) The axial unit stress in member EB.
(b) The axial unit stress in member AE.
(c) The average shearing unit stress in the pin at A.

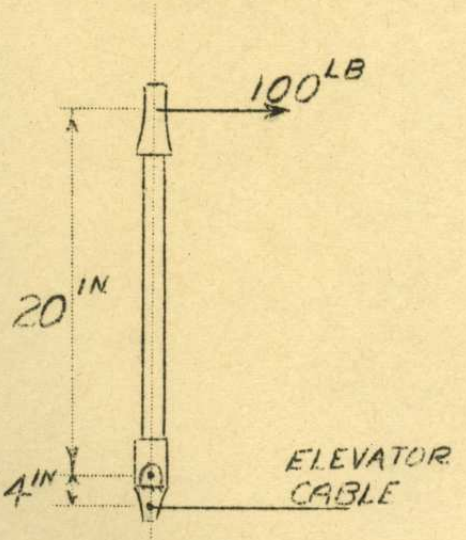


FIG. 1D-2

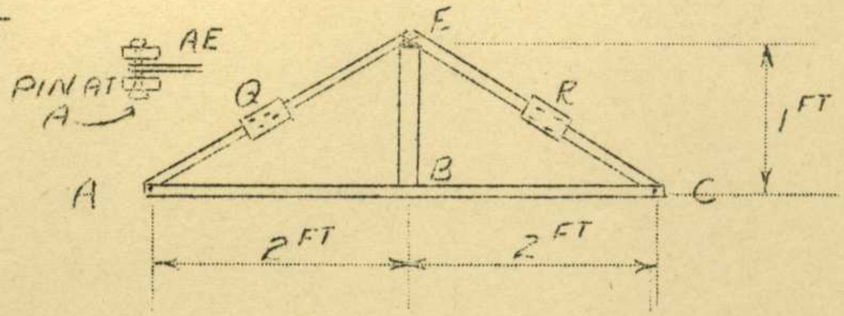


FIG. 1D-3

2D-1. The propellor of a given airplane develops a thrust of 3000 lb. during take-off. Determine the maximum tensile and shearing stresses which the thrust develops in the drive shaft of the propellor if the shaft has an outside diameter of 3.00 in. and an inside diameter of 2.50 inches. Note: Additional stresses are developed in the shaft by the torque and by bending. These stresses will be considered later.

2D-2. A 1-in. diameter bar is subjected to an axial load of 12,000 lb. Determine the tensile and shearing unit stresses on a plane and that makes an angle of 30° with the axis of the rod.

2D-3. At a certain point in a structural steel member there is a horizontal tensile stress of 800 p.s.i. and a vertical compressive stress of 1000 p.s.i. as shown in Fig. 2D-3. Determine the unit stress on a plane through the point inclined 30° to the horizontal.

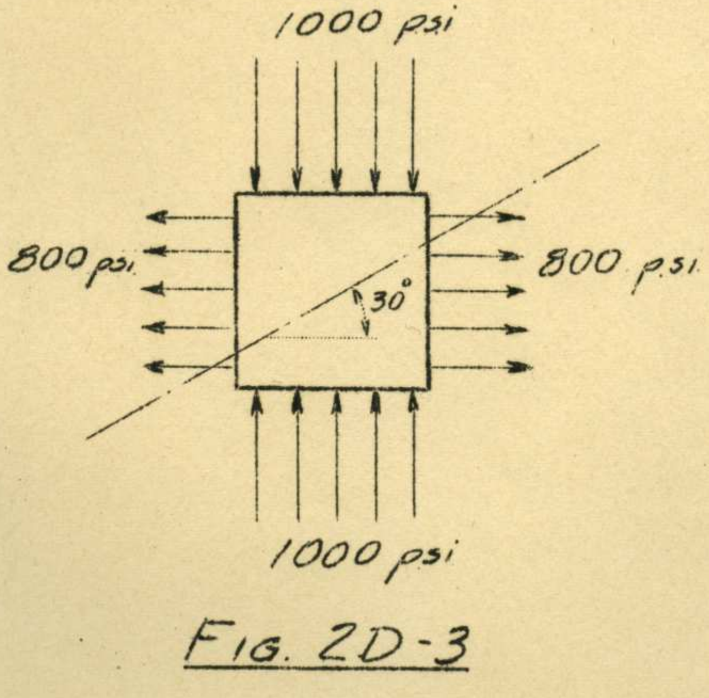


FIG. 2D-3

MECHANICS OF MATERIALS | PROBLEMS | CURTISS-WRIGHT ENGINEERING
Course B-4 | Seely; Art 6-7, 9,10 | CADETTES 3D-A-108

3D-1. Determine the minimum width of expansion joint necessary for a concrete slab 50 feet long. The temperature range can be taken from -32° F. to + 125°F.

3D-2. Fig. 3D-2 shows one of the two trusses used for an engine mount. The loads indicated are due to engine weight, thrust and torque. Member BC is constructed from 3/4 in. O.D. hollow tubing. Determine the minimum thickness of tubing necessary for member BC if the working stress is 40,000 p.s.i. Assume the truss to be pin connected.

3D-3. A surveyor's steel tape, 100 ft. long at 62°F under a pull of 12 lb., is used to measure a given distance. The tape is used ata tempererature of 97° and the chainmen exert a tension of 35 lb. How great an error has been introduced in going 10 tape lengths? The cross-sectional area of the tape is 0.01 sq. in.

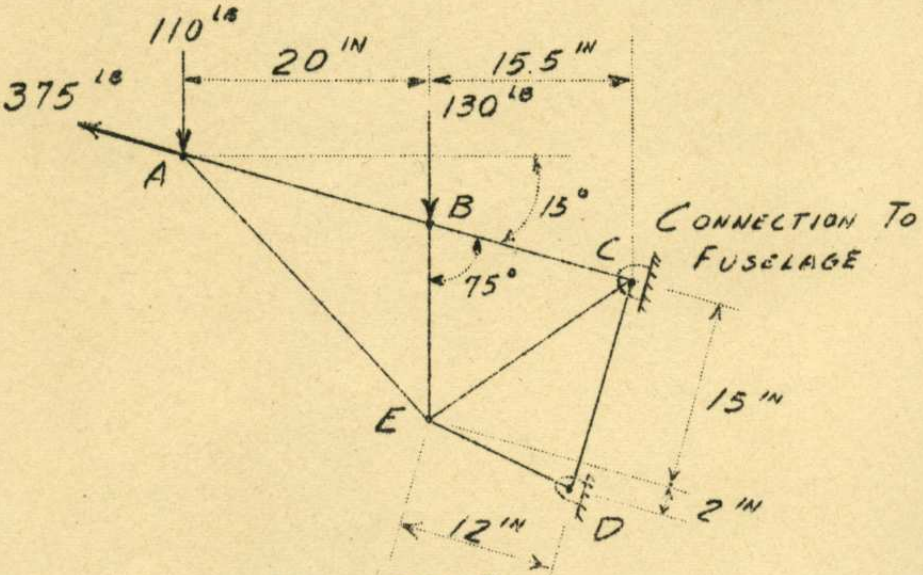


FIG. 3D-2

Seely; Art. 12-14

4D-1. A supply tank 18 ft. in diameter and 40 ft. high is filled with gasoline. What is the circumferential unit stress at the bottom of the supply tank if the thickness of the plate is 5/16 in.? The specific gravity of gasoline is 0.70.

4D-2. The two hemispherical sections of a 40-ft. diameter gas holder are joined by a lap joint. The gas pressure is 30 p.s.i.

(a) Determine the total force transmitted across a 6-in. length of the joint.

(b) Determine the average normal unit stress in the plate on the net section A-A Fig. 4D-2 if the rivet holes are 7/8 in. in diameter and the plate is 1/2 in. thick.

4D-3. A steel pipe 24 in. in diameter has a welded spiral seam as shown in Fig. 4D-3. The pressure inside the pipe is 120 p.s.i. Determine the normal and shearing forces which must be carried by each linear inch of the weld. Assume that ther is no longitudinal stress in the pipe.

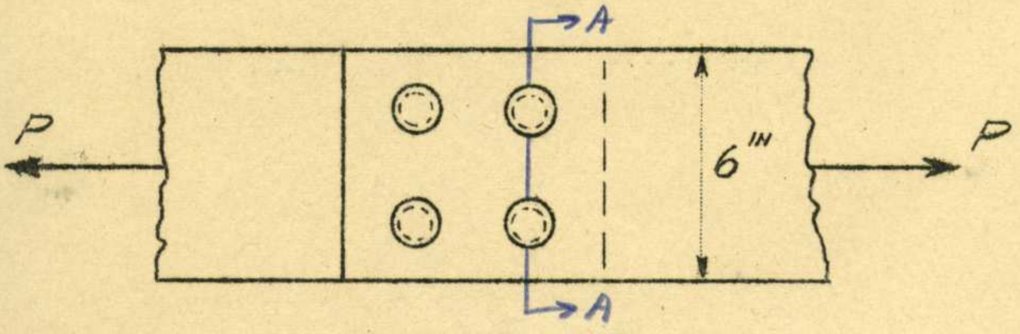


FIG. 4D-2

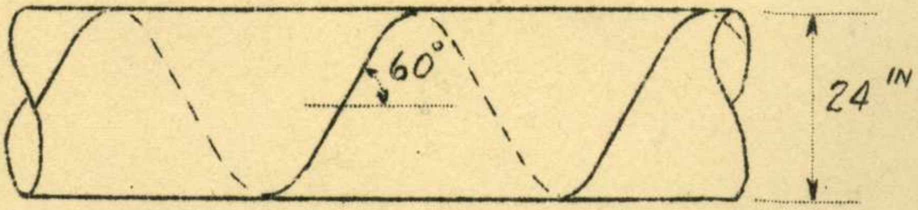


FIG. 4D-3

5D-1. The riveted joint shown in Fig. 5D-1 is part of a wing spar. The top chord, vertical and diagonal members are 2-in. aluminum channels. The gusset plate is 3/16 in. in thickness. All rivets are 3/8 in. in diameter. Determine:
   (a) The average bearing unit stress in channel B.
   (b) The average shearing unit stress in the rivets connecting member A to the gusset plate.

5D-2. Two 1/2-in. plates are connected by means of a double riveted butt joint as shown in Fig. 5D-2. The cover plates are 3/8" thick and the rivets are 1. in. in diameter. The allowable stresses are: F_s = 9000. psi, F_t = 11,000 psi, and F_b = 19,000 psi. Determine the efficiency of the joint and the maximum allowable load, P, which the joint will carry.

5D-3. A double riveted butt joint with 2 cover plates has a unit tensile stress in the gross section of the main plates of 32,000 psi. The main plates are 0.128 in. thick, and the cover plates are 0.072 in. thick. The 5/16-in. rivets are spaced at 1 in. in the inner rows and 3 in. in the outer rows, and the rows are 1 1/4 in. apart. Edge distances are 5/8 in. The plates are of 24 S-T, and the rivets are of A17S-T aluminum alloy. Determine:
   (a) The total shearing stress per rivet shear area.
   (b) The total bearing stress per rivet.
   (c) The maximum unit tensile stress in main and cover plates.
   (d) The margin of safety with respect to the ANC-5 values for parts (a) and (b).

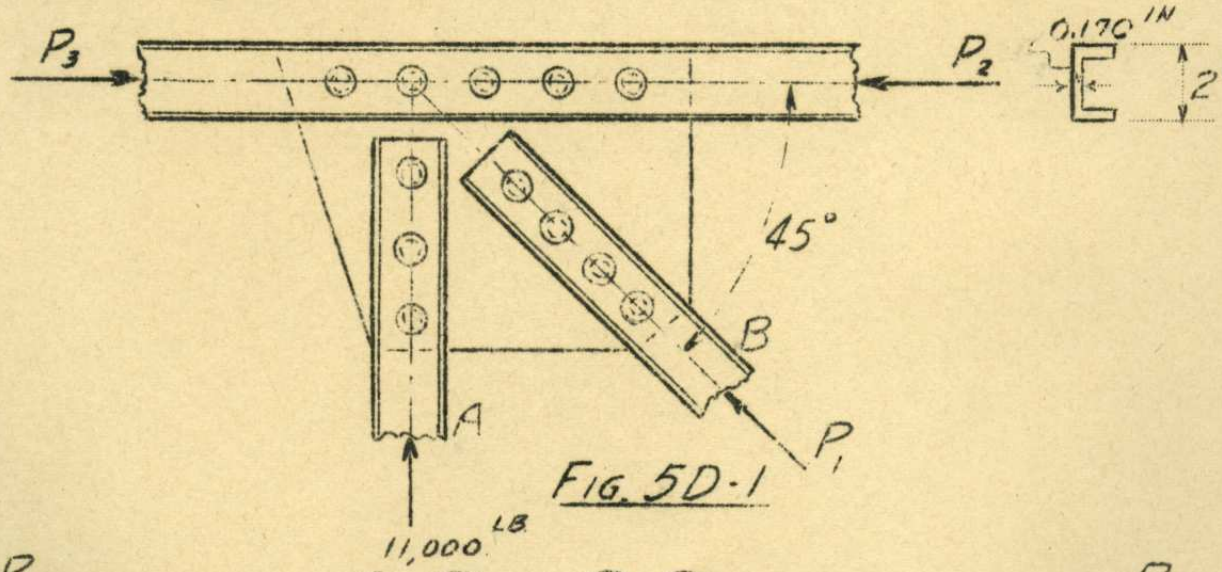


FIG. 5D-1

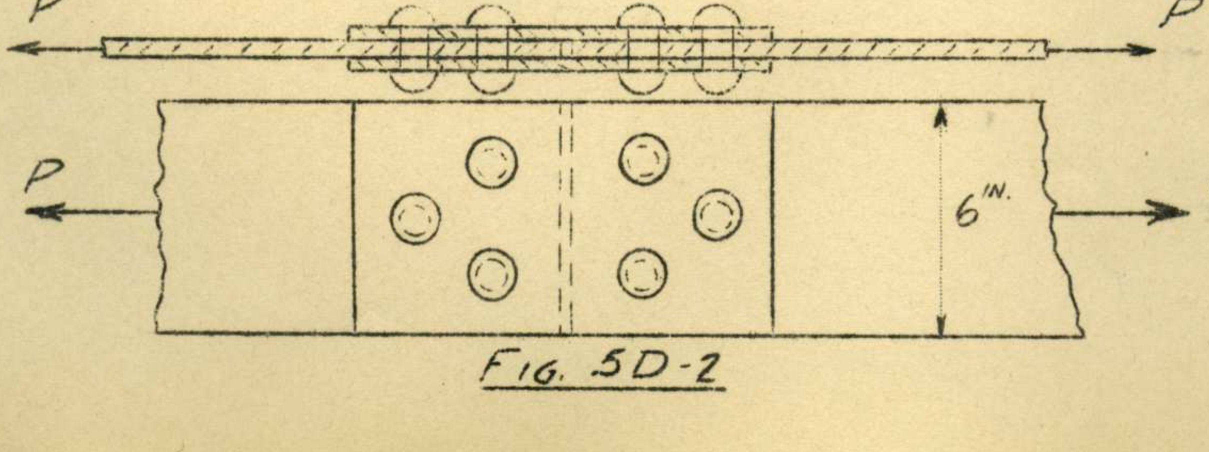


FIG. 5D-2

6D-1 A pair of 2 by 1 1/2 by 1/4 in. carbon steel angles are to be welded to a 1/4-in. steel plate as indicated in Fig. 6D-1. Determine the length of 1/4-in. fillet weld required on each side of the angles if the connection is to transmit the 25,000 lb. load without any moment being developed at the joint.

6D-2 Design 1/4-in. fillet welds to connect the structural steel angles A and B in Fig. 6D-2 to the gusset plate. The fillet weld is to be placed transverse to the direction of the load as well as on each side of the angles.

6D-3 Fig. 6D-3 shows part of an all-welded floor joist for heavy construction. Design the welded joint at A to develop the full strength of the angle at a unit stress of 14,000 psi for the angle and 2000 lb. per linear inch for the welds. The cross-sectional area of the angle is 0.94 sq. in.

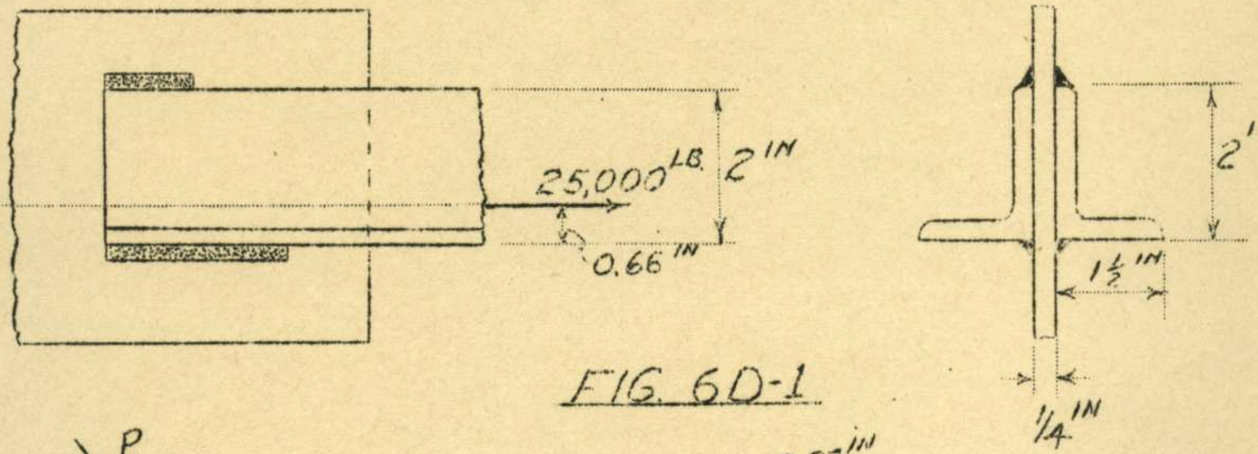


FIG. 6D-1

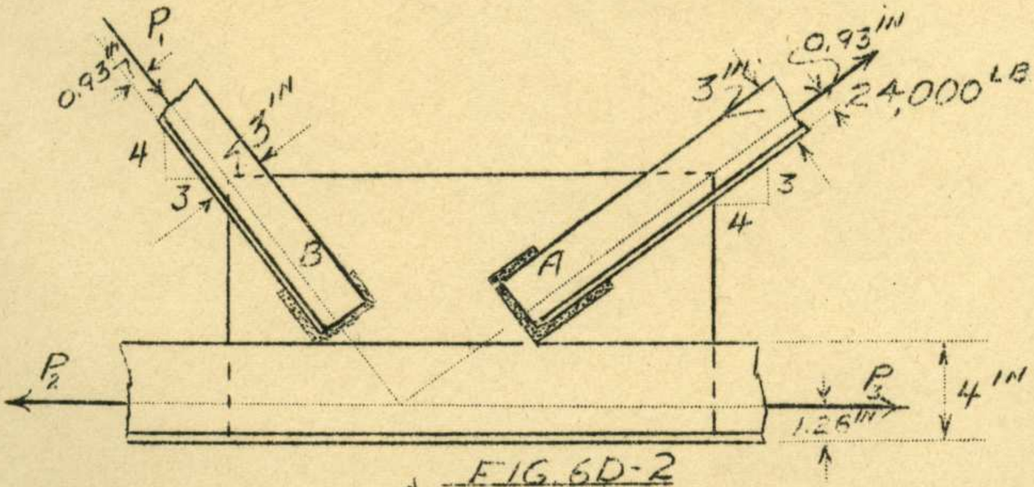


FIG. 6D-2

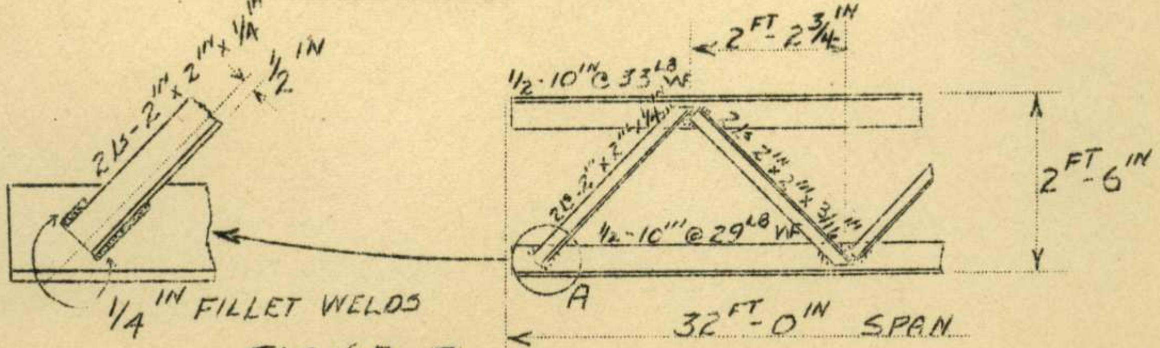


FIG. 6D-3

MECHANICS OF MATERIALS PROBLEMS CURTISS-WRIGHT ENGINEERING
Course B-4 Seely; Art; 20-22 CADETTES 7D-A-112

7D-1 A solid steel shaft 2 in. in diameter and 5 ft. long is fixed at one end. A clockwise torque of 2500 ft. lbs. is applied at the free end of the shaft. A counter-clockwise torque of 1500 ft. lb. is applied at the midpoint of the shaft.

(a) Determine the torsional shearing unit stress at the surface of the shaft at the fixed end.

(b) Determine the torsional shearing unit stress at a point 1/2 in. from the surface and one foot from the free end.

7D-2 Design a hollow shaft to resist a torque of 500,000 in. lb. with a maximum torsional shearing unit stress of 10,000 p.s.i. The internal diameter is to be one-half of the external diameter.

7D-3 Fig. 7D-3 shows a control column and torque tube for an airplane. For the load shown determine the maximum unit torsional shearing stress in the torque tube.

7D-4 The aft fuselage of the P-39 is of semi-monocoque construction using a .032-in. sheet aluminum skin. Determine the torque which would be required to produce a torsional shearing unit stress of 24,000 p.s.i. at a section 25 in. in diameter if the effect of the longerons is neglected.

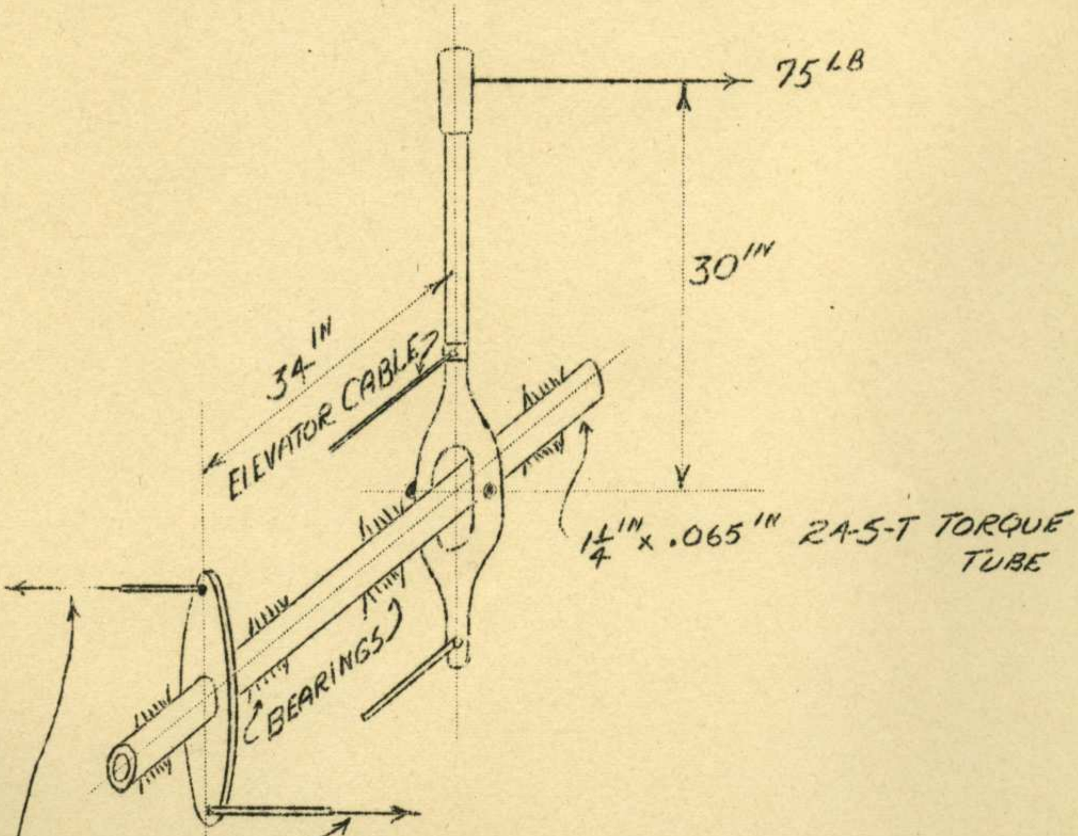


FIG 7D-3

MECHANICS OF MATERIALS PROBLEMS CURTISS-WRIGHT ENGINEERING
Course B-4 Seely; Art. 23-24; 26 CADETTES 8D-A-113

8D-1 Determine the angle of twist in the torque tube of problem 7D-3.

8D-2 Fig. 8D-2 indicates a set-up for measuring angle of twist during a torsion test. The dial at A will indicate the distance S thru which the end of the arm OA travels relative to B. From the distance S, the angle θ can be computed readily. If the tube shown is 24S-T having a proportional limit of 18,000 p.s.i. in shear, and the dial has a least count of $\frac{1}{1000}$ in., determine the dial increments which will provide ten readings within the range in which stress is proportional to strain.

8D-3 The airplane shown in Fig. 8D-3 is travelling at the rate of 200 m.p.h. and the propeller is turning over at the rate of 1800 r.p.m. The hollow drive shaft has an outside diameter of 5. in. and an inside diameter of 4. in. If the propeller has an efficiency of 75% determine the maximum torsional shearing unit stress in the shaft due to the resisting torque developed by the propeller.

8D-4 The drive shaft of an airplane using an Allison V1710 engine is 10 ft. long. If the shaft has an external diameter of 2.00 in. and an internal diameter of 1.25 in., determine:

(a) The maximum shearing stress in the shaft when the output of the engine is 1200 horsepower at 3000 r.p.m.
(b) The length of arc through which the tip of the propeller is displaced due to the twist in the drive shaft between the zero load condition and the condition indicated in (a). The propeller circle is 124.5 in. in diameter and the gear reduction of the propeller is 2:1 (i.e., the r.p.m. of the drive shaft is twice the r.p.m. of the propeller). Neglect deflection in the gears.

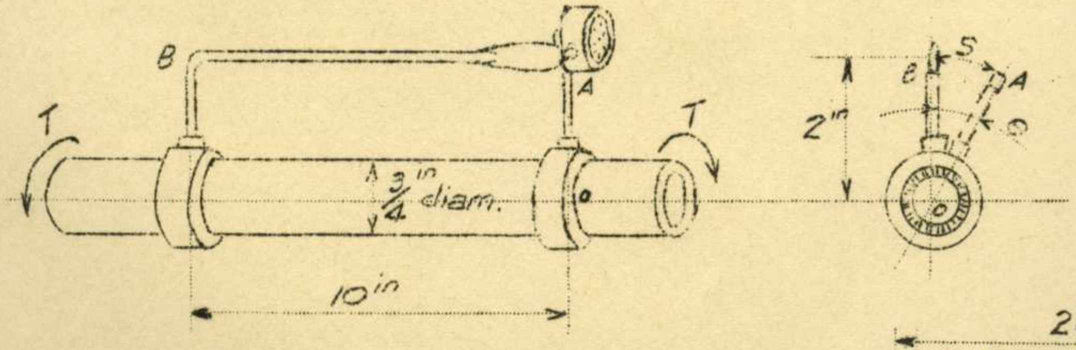


FIG. 8D-2

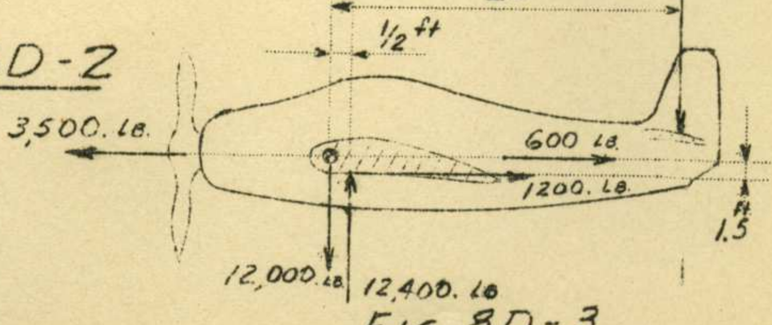


FIG. 8D-3

MECHANICS OF MATERIALS PROBLEMS CURTISS-WRIGHT ENGINEERING
Course B-4 Seely; Art. 27-28 CADETTES 9-D-A-114

9D-1 A propellor shaft which transmits 1750 h.p. at 2500 r.p.m. has a flange coupling (see Fig. 7D, p. 68 in Seely) with a 4-in. diameter bolt circle. How many 3/8-in. bolts are necessary for the coupling if the bolts are of heat-treated alloy steel with an ultimate shearing strength of 65,000 p.s.i., and if a factor of safety of 1.5 with respect to failure by fracture is specified?

9D-2 At a certain point in a propellor shaft there are normal and shearing unit stresses as shown in Fig. 9D-2. Determine the normal and shearing unit stresses on the plane A-A.

9D-3 (a) Determine the maximum tensile stress caused by the torsional loading on the shaft in Fig. 9D-3.

(b) Determine the angle of twist of the free end of the shaft.

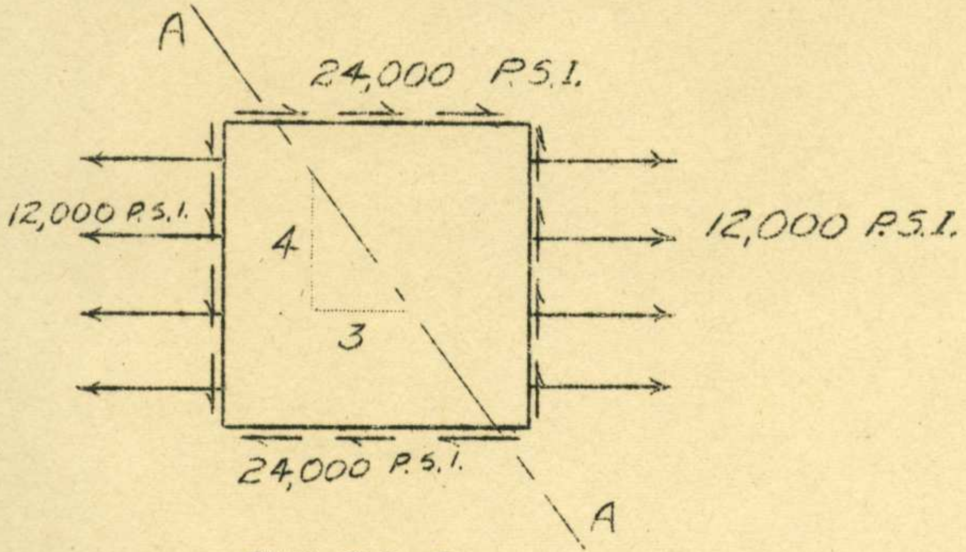


FIG. 9D-2

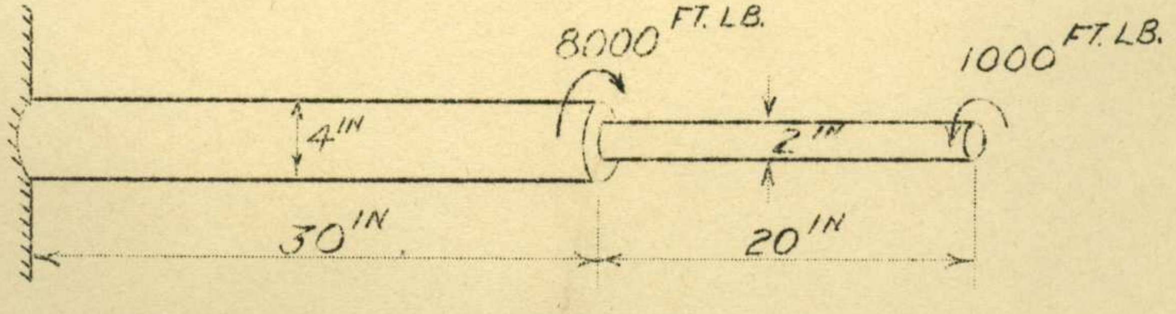


FIG. 9D-3

Cwp.

MECHANICS OF MATERIALS   REVIEW PROBLEMS   CURTISS-WRIGHT ENGINEERING
Course B-4   Art; 1-28   CADETTES   10D-A-115

10D-1 Two .081-in. aluminum plates are to be connected by a triple riveted lap joint. The pitch of the inner row of rivets is 1 in. and that of the outer rows is 1.5 in. The rivets are 1/4 in. in diameter. Determine the maximum load per foot which the joint may transmit without exceeding the following stresses: F_s = 35,000 p.s.i.; F_{br} = 82,000 p.s.i.; F_t = 56,000 p.s.i. Determine the efficiency of the joint.

10D-2 An engine develops 1900 b.h.p. at a speed of 1800 r.p.m. A 3-in. hollow drive shaft .165 in. thick, Fig. 10D-2, transmits the horsepower developed by the engine to the propellor. The propellor has an efficiency of 80% and the airplane is travelling at 180 m.p.h. Determine the normal and shearing unit stresses at point A on a plane that makes an angle of 30° with the horizontal.

10D-3 The solid shaft B in Fig. 10D-3 is welded to shaft A by means of a circumferential fillet weld. The maximum torsional shearing unit stress delveloped in shaft B is 24,000 p.s.i. Determine the required strength of the weld per inch if the weld is designed with a margin of safety of 0.75.

10D-4 (a) Determine the maximum shearing unit stress in the shaft of Fig. 10D-4.

(b) Determine the angle of twist of the free end, in degrees, if the shaft is made of 24S-T aluminum alloy.

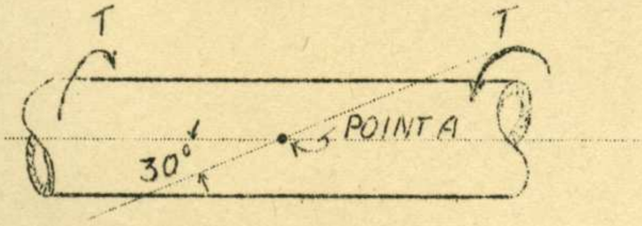


FIG. 10D-2

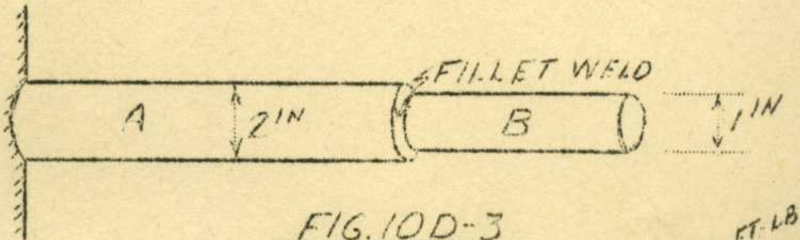


FIG. 10D-3

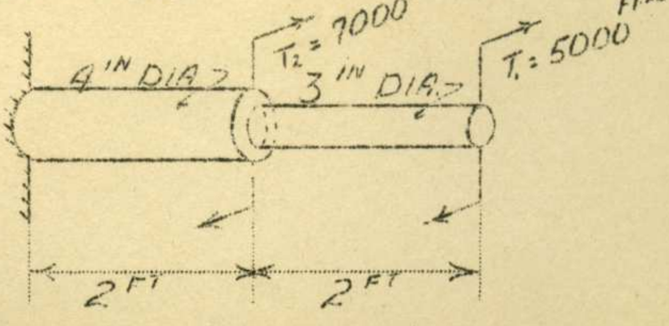


FIG. 10D-4

MECHANICS OF MATERIALS QUIZ I(84312) CURTISS-WRIGHT ENGINEERING
Course B-4 Seely: Arts. 1-28 CADETTES 11D-ZC3-116

NOTE: Show all work, including scratchwork, in blue book. Do not copy original questions in blue book. Return these questions with blue book.

1. A 1-in. diameter duralumin rod 10 ft. long has the ends fastened to supports which may be assumed to be rigid. The maximum normal stress in the rod at a temperature of 100° F. is 2000 p.s.i. tension. Determine the unit normal, and shearing stresses in the rod on a plane making an angle of 30° with the longitudinal axis of the rod, when the temperature is 20° F. The coefficient of thermal expansion is 0.0000114 and E is 10,500,000 p.s.i.

2. The longitudinal seam for a cylindrical compressed-air tank 20 in. in diameter is to be a double-riveted butt joint with 2 cover plates The main plate is 0.102-in. 24S-T aluminum alloy sheet, and the 1/4-in. A17S-T rivets are spaced at 3/4 in. in the inner rows and 1 1/2 in. in the outer rows. Using the following safe working values, and neglecting tension in the cover plates, determine the maximum permissible pressure in the tank:
   Single shear 660 Lb./rivet Bearing 1150 Lb./rivet
   Tension in sheet 31,000 p.s.i.

3. A 3-in. diameter steel tube with a wall thickness of 1/4 in. is to be used as a shaft for transmitting power. It is specified that the torsional shearing unit stress shall not exceed 40,000 p.s.i., and the angle of twist shall not exceed $\frac{L}{600}$, where L is the length of the shaft in inches. What maximum torque may be applied without exceeding these specifications? G = 12,000,000 p.s.i. and E = 30,000,000 p.s.i.

4. Figure 1 represents a flange coupling for a drive shaft. If the bolts are 1/4 in. in diameter, what maximum horsepower may be transmitted at 1800 r.p.m. without exceeding a shearing stress of 2000 Lb./bolt?

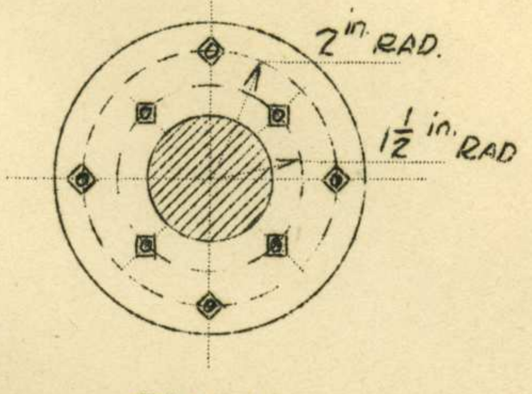


FIG. 1

MECHANICS OF MATERIALS QUIZ 1(84313) CURTISS-WRIGHT ENGINEERING
Course B-4 Seely; Art. 1-28 CADETTES 11D-HWZ-117

NOTE: Show all work, including scratchwork, in blue book. Do not copy original questions in blue book. Return these questions with blue book.

1. An oxygen supply tank 3 ft. in diameter and 6 ft. long is under an internal pressure of 60 p.s.i. Determine:
   (a) The force which must be carried by each inch of a longitudinal welded joint.
   (b) The force which must be carried by each inch of a transverse welded joint.

2. (a) A 2.75 in. diameter 17S tube with a wall thickness of .500 in. is subjected to a torque of 4000 ft. lb. Determine the unit shearing stress at the inner wall of the tube.

   (b) At a certain point in a structural member the stresses shown in Fig. 2b exist. Determine the normal and shearing unit stresses on a plane that makes an angle of 30° with the horizontal.

3. Two steel plates which are 4 in. wide and 3/16 in. thick are joined by means of a double riveted lap joint as shown in Fig. 3. The rivets are 1/2 in. in diameter. Determine:

   (a) The average unit shearing stress in the rivets.

   (b) The average bearing unit stress of the plates on the rivets.

   (c) The maximum average tensile unit stress and state where it occurs.

4. The drag truss in Fig. 4 is loaded as shown during a given flight condition. The drag wires which have a diameter of 1/8 in. are an alloy steel with a modulus of elasticity of 29,000,000 p.s.i. Determine:

   (a) The unit tensile stress in drag wire AI.

   (b) The total elongation of the drag wire AI.

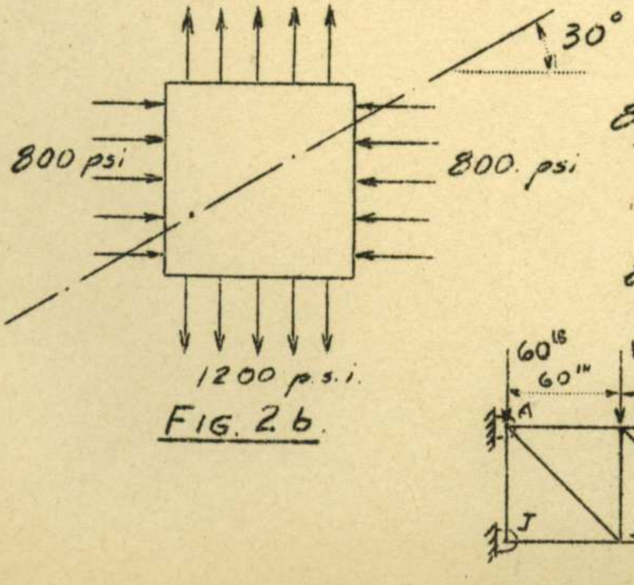


FIG. 2 b.

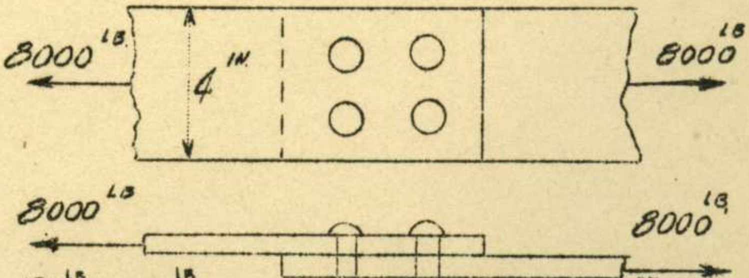


FIG. 3

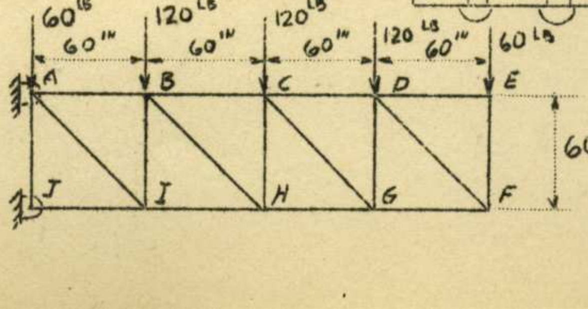


FIG. 4

MECHANICS OF MATERIALS QUIZ I (84313) CURTISS-WRIGHT ENGINEERING
Course B-4 Seely: Arts. 1-28 CADETTES 11D-UH1-118

1. (a) Determine the axial stress which will be developed in a streamline aluminum alloy tubing strut due to a temperature drop of 60°F if there is no change in length of the strut. The length of the strut is 30 in.; its cross-sectional area is 0.106 sq. in., and the coefficient of thermal expansion of aluminum is 0.000012 per degree F. The modulus of elasticity of aluminum alloys is 10,000,000 p.s.i.

   (b) At a point on the surface of a propeller shaft of an airplane in a climb are horizontal tensile stresses of 12,000 p.s.i. and vertical compressive stresses of 2000 p.s.i. Determine the stresses which act on a plane at the point making an angle of 30° with the horizontal.

2. (a) A cylindrical compressed air tank is 20 in. in diameter is made of 1/8 in. plates. Determine the maximum tensile stress in the plate if the internal pressure is 100 p.s.i.

   (b) A 2" x 2" x 1/8" angle is to be welded to a gusset plate in a truss constructio The angle carries a stress of 20,000 p.s.i. and the weld will transmit 1000 lb. per inch. Design the connection so that there will be no bending at the joint and so that the length of welds on the sides of the angle shall be as small as possible. The cross sectional area of the angle is 0.48 sq. in. and its centroidal axis is located 0.55 in. from the back of the angle.

3. A hollow steel propeller shaft transmits 685 H.P. when turning over at 1800 r.p.m. The outer diameter is 4 in. and the inner diameter 2 in. Es for steel is 12,000,000 p.s.i.
   (a) Determine the maximum shearing unit stress in the shaft.
   (b) Determine the angle of twist in a 1 ft. length of the shaft.

4. Two 0.102-in. plates are to be connected by a double riveted butt joint with two cover plates. The pitch of the rivets in the inner row is 1 in. and in the outer row 3 in. The rivets are $\frac{1}{2}$" in diameter. Using a 3-in. length of joint, determine the efficiency. The following unit stresses are not to be exceeded. F_{br} = 30,000 p.s.i., F_s = 10,000 p.s.i.; F_t = 15,000 p.s.i. Tension in the cover plates may be neglected.

MECHANICS OF MATERIALS PROBLEMS CURTISS-WRIGHT ENGINEERING
Course B-4 Seely; Art. 29-31 CADETTES 12D-A-119

12D-1. The unit fiber stress at point A in a spruce box spar with a cross-section as shown in Fig. 12D-1 is 3,500 p.s.i. compression. The beam is subjected to loads which produce bending about a horizontal axis. Determine the bending moment in the beam at the section shown.

12D-2. The maximum unit fiber stress in a beam with the cross-section shown in Fig. 12D-2 is 1500 p.s.i. tension. If the beam is subjected to loads which produce bending about a horizontal axis, determine:

(a) The maximum compressive unit fiber stress.
(b) The total fiber stress carried by the flange.

12D-3. A simple beam 10 ft. long carries a uniformly distributed load of 100 lb. per ft. and a concentrated load of 1000 lb. at its midpoint. The beam has a rectangular cross section 4 in. wide and 8 in. deep. Determine the maximum tensile fiber unit stress at the section under the concentrated load.

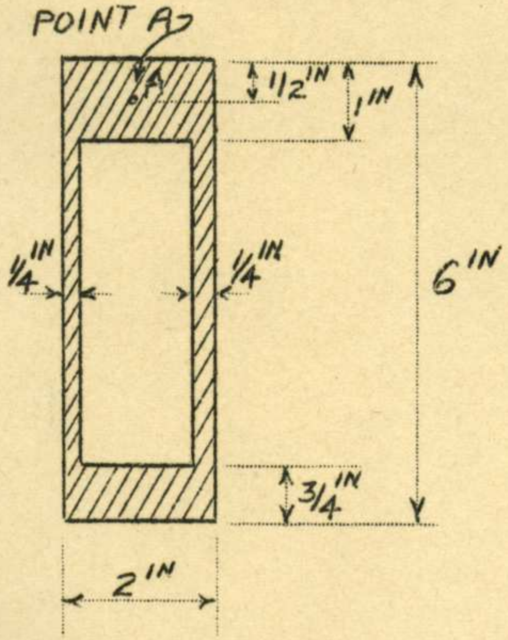


FIG. 12D-1

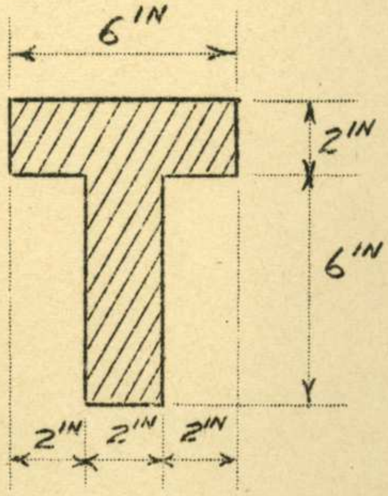


FIG. 12D-2

13D-1. Draw complete shear and moment diagrams for the beam loaded as shown in Fig. 13D-1.

13D-2. Draw complete shear and moment diagrams for the wing loaded as shown in Fig. 13D-2.

13D-3. Draw complete shear and moment diagrams for the wing loaded as shown in Fig. 13D-3. (Note: neglect the moment due to the horizontal component of the flying wire reaction).

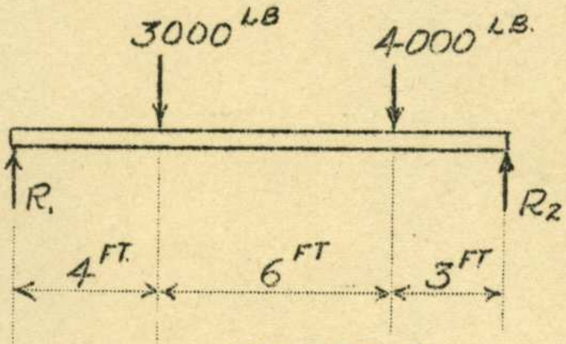


FIG. 13D-1

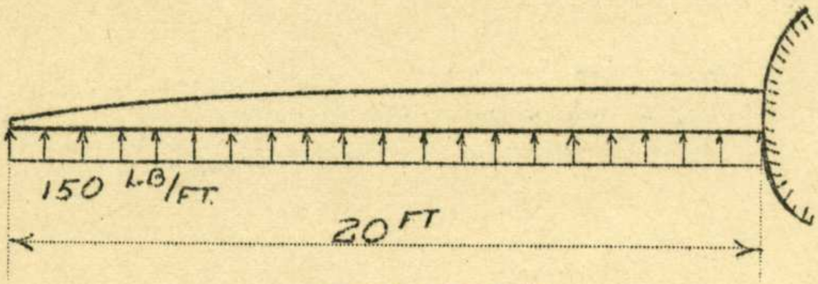


FIG. 13D-2

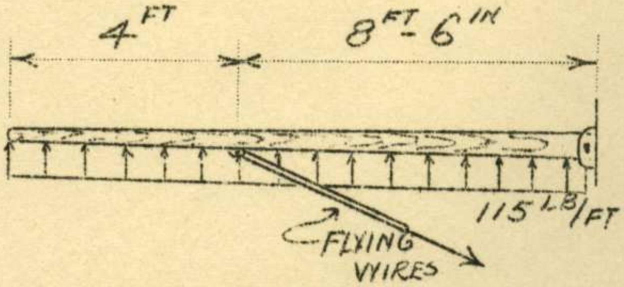


FIG. 13D-3

14D-1. Draw complete shear and moment diagrams for the left wing (from ℄ outboard) shown in Fig. 14D-1. Neglect the weight of the wing and the moment due the horizontal component of the flying wire reaction.

14D-2. Draw the complete shear and moment diagrams for the beam shown in Fig. 14D-2.

14D-3. Fig. 14D-3 represents a column for a mill building. The bracket at A carries a crane rail, and the crane reaction, P, is 10,000 lb. Draw the shear and moment diagrams, assuming that the distance of P from the center line of the column remains 1.2 ft. at all sections.

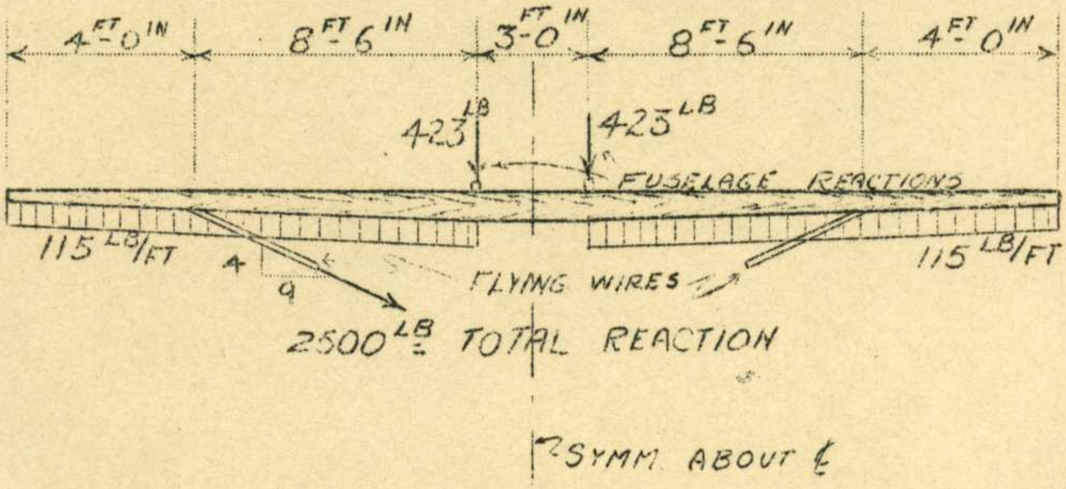


FIG. 14D-1

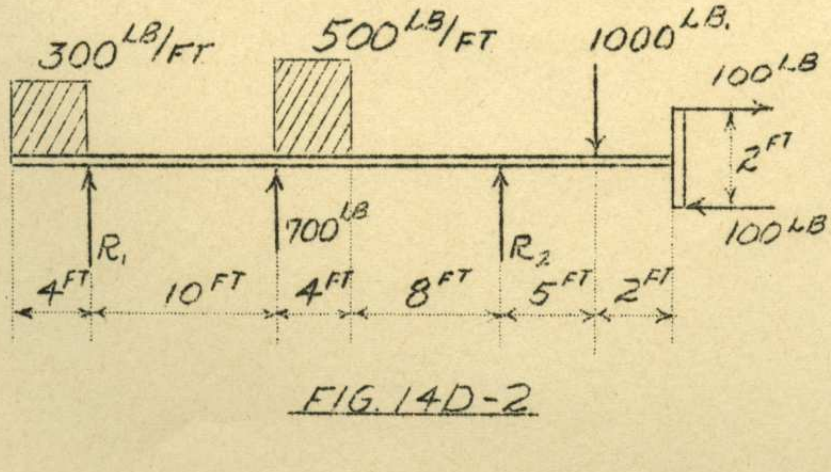


FIG. 14D-2.

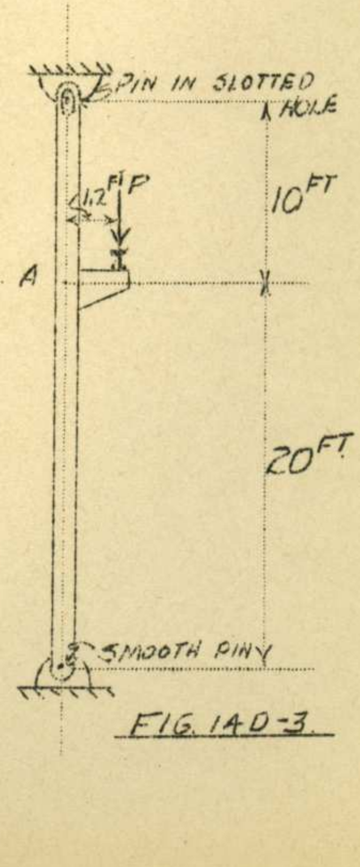


FIG. 14D-3.

MECHANICS OF MATERIALS PROBLEMS CURTISS-WRIGHT ENGINEERING
Course B-4 Seely: Arts. 38-39;41 CADETTES 15D-A-122

15D-1. Fig. 15D-1 shows the cross-section of a wing spar. Determine the unit shearing stress one inch from the top of the beam if the external shear is 200 lb.

15D-2. A hollow steel tube is used as a beam 8 ft. long. It is simply supported at points 2 ft. from each end and carries a downward load of 2,000 lb. at each end. It also carries a uniform load of 500 lb./ft. between the supports. The OD is 2 in. and the thickness is $\frac{1}{4}$ in. Determine the maximum vertical shearing unit stress in the beam.

15D-3. The cross-section of a solid spruce spar is shown in Fig. 15D-3. The spar is 14 ft. long and is cantilevered to the fuselage of the airplane. The modulus of rupture for spruce may be taken as 8,000 p.s.i.

- (a) Determine the maximum uniformly distributed load which can be applied to the wing spar with a load factor of 4 if the modulus of rupture governs the design.
- (b) Determine the maximum longitudinal unit shearing stress in the wing spar due to the design load obtained in part (a).

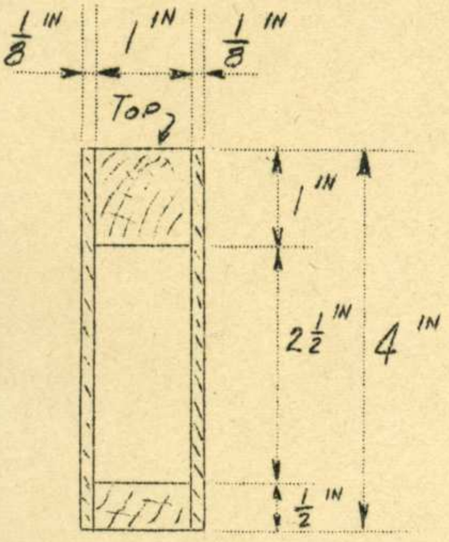


FIG. 15D-1

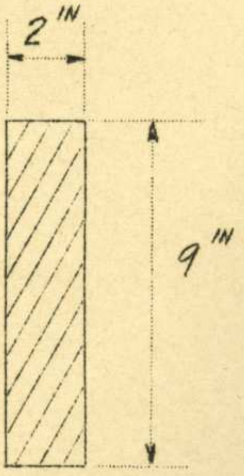


FIG. 15D-3

MECHANICS OF MATERIALS PROBLEMS CURTISS-WRIGHT ENGINEERING
Course B-4 Seely: Arts. 29-41 CADETTES 16D-A-123

16D-1. Fig. 16D-1 (a) shows a wood airplane rib. For convenience, assume a chordwise load distribution as shown in (b), and draw complete shear and moment diagrams for the rib.

16D-2. Using a load factor of 4, determine the maximum fiber unit stress in the rib of problem 16D-1. Note that the resisting section for moment at spar cut-outs consists of cap strips only.

16D-3. Determine, for the rib of problem 16D-1, the shearing unit stress at the junction of cap strip and web on section A-A. Use a load factor of 4.

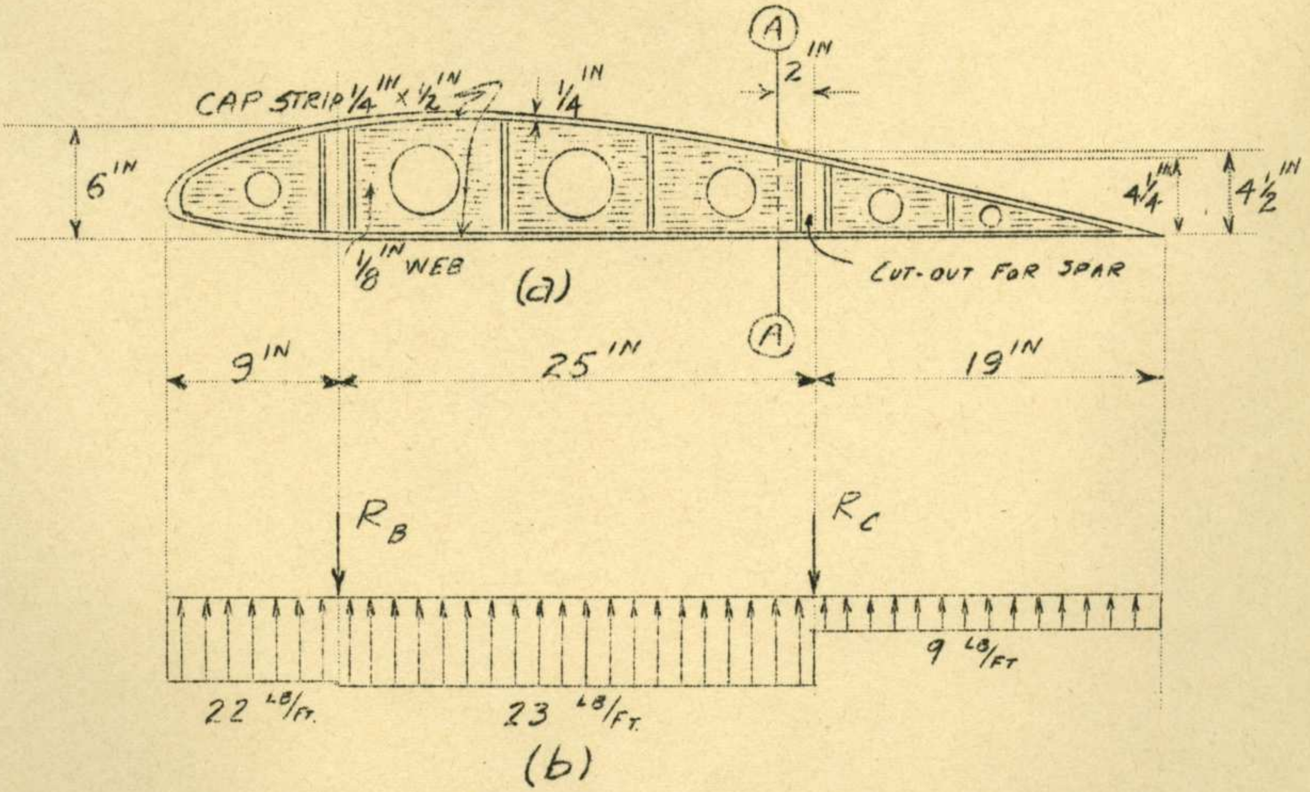


FIG. 16D-1

16DO-1. Fig. 16DO-1 shows the cross section of a spruce box wing spar. The spar is 16 ft. long and cantilevered to the fuselage. Determine the maximum uniformly distributed load that can be applied to the wing spar if the unit shearing stress is not to exceed 300 p.s.i. and the unit tensile stress is not to exceed 6,000 p.s.i.

16DO-2. The beam shown in Fig. 16DO-2(a) is partially restrained at the right end and has a cross section as shown in Fig. 16DO-2(b). Determine the maximum tensile unit stress in the beam. Ans. 3410 p.s.i.

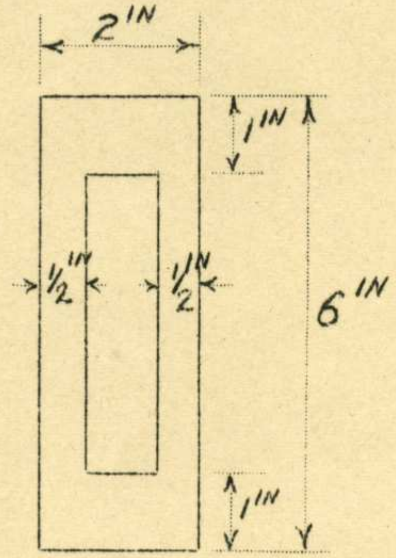


FIG. 16DO-1

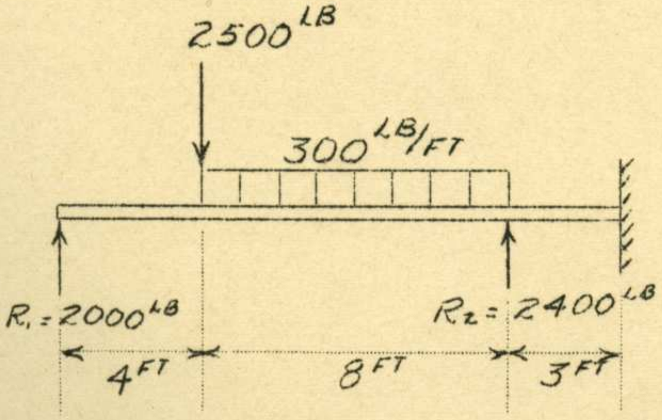


FIG. 16DO-2(a)

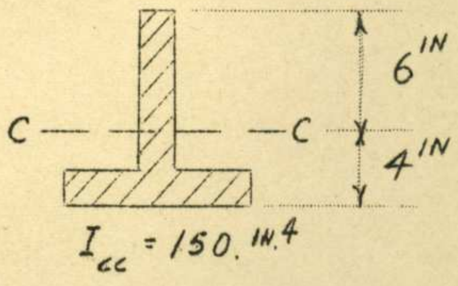


FIG. 16DO-2(b)

MECHANICS OF MATERIALS
course B-4

PROBLEMS
Seely: Art. 116-117

CURTISS-WRIGHT ENGINEERING
CADETTES 17D-A

17D-1. An aluminum alloy bar 1 in. wide, 2 in. deep and 20 in. long is used as a cantilever beam. The maximum allowable fiber unit stress in the beam is 15,000 p.s.i.

(a) Determine the maximum load P which may be applied at the mid-point of the beam if the allowable fiber stress governs the design.

(b) Determine the deflection of the mid-point of the beam. How does the result compare with that obtained by using equation 71 in the text?

(c) Determine the deflection of the free end of the beam by the conjugate beam method.

(d) Check the deflection of the free end using the slope and deflection of the mid-point.

17D-2 In Fig. 17D-2 is shown the cross-section of a cantilever wing spar which is built up of $1\frac{1}{2}$ in. x .064 in. x 4130 steel tubes with an .064 in. web plate which has cut-outs for lightness. Neglect the web plate in the computation for I. The span is 10 ft., and the load may be assumed to be 50 lb./ ft. upward. Determine the maximum deflection.

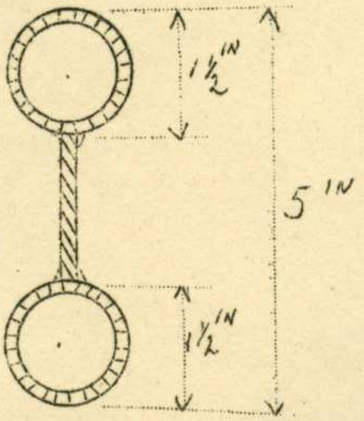


FIG. 17 D·2

MECHANICS of MATERIALS Course B-4

PROBLEMS Seely: Art. 118-121

CURTISS-WRIGHT ENGINEERING CADETTES 18D-A-126

18D-1 The structural steel beam in Fig. 18D-1 is loaded as shown. Determine the maximum deflection in the main span, and in the overhang. Neglect the weight of the beam.

18D-2 Fig. 18D-2 shows a flag pole made by nesting steel tubes and welding them together. If the horizontal component of the flag pull at the top is 20 lb., determine the maximum deflection of the pole. Neglect vertical loads and assume an abrupt change of I at each joint.

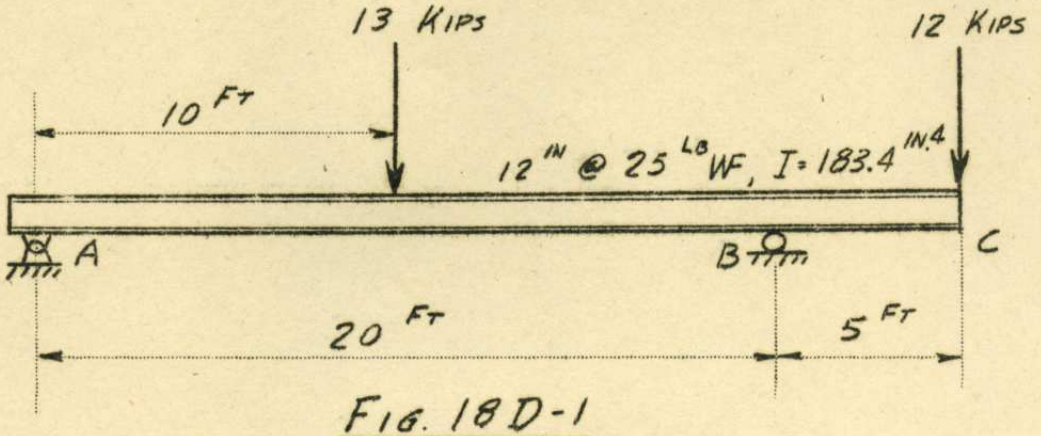


FIG. 18D-1

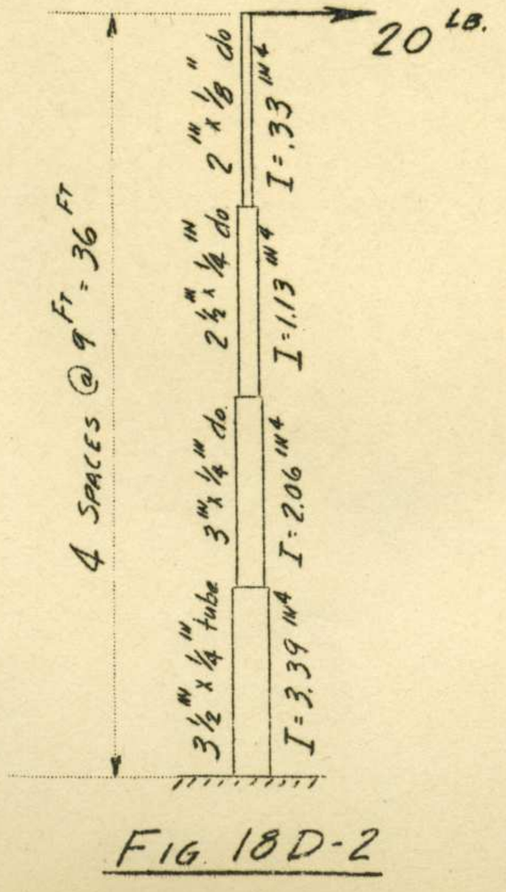


FIG. 18D-2

MECHANICS OF MATERIALS
Course B-4

PROBLEMS
Seely: Art. 118-121

CURTISS-WRIGHT ENGINEERING
CADETTES 19D-A-127

19D-1. A horizontal beam 5 ft. long is fixed at the right end and simply supported at the left end. The beam carries a uniform load of 300 lb. per foot. The cross section of the beam is shown in Fig. 19D-1.

(a) Determine the value of the reaction at the simple support.

(b) Write the expression for the slope of the beam at both ends and at the mid-point in terms of w, E, I, L.

(c) What is the maximum fiber stress in the beam?

19D-2. Consider the wing shown in Fig. 19D-2 to be fixed at the fuselage. For the loading shown, determine the tension in each flying wire if there are two of them, each carrying half the reaction at B; and the slope of each wire is 3 vertical, 9 lateral, and $1\frac{1}{2}$ longitudinal (referring to the axes of the airplane). Assume the wires to be rigid, and neglect the effect of the lateral components of the flying wire reactions on the moment in the spars.

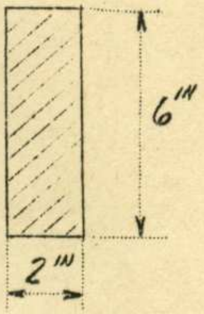


Fig 19 D-1

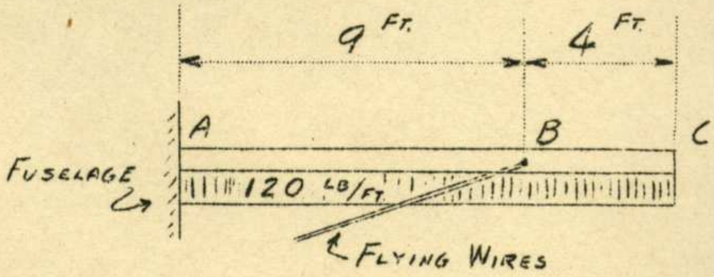


Fig 19 D-2

20D-1. Draw complete shear and moment diagrams for the beam loaded as shown in Fig. 20D-1.

20D-2. For the biplane shown in Fig. 20D-2 assume a spanwise lift distribution of 60 lb./ft. on the upper wing and draw complete shear and moment diagrams for the upper wing. Assume the supports at A, B, C, E, D are unyielding and that the wing spars have constant moment of inertia.

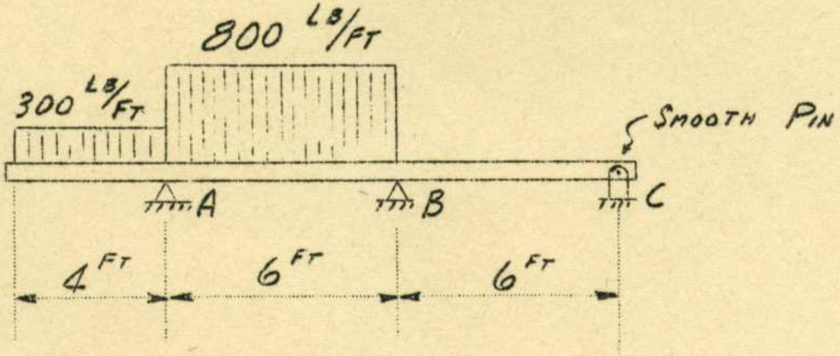


FIG 20D-1

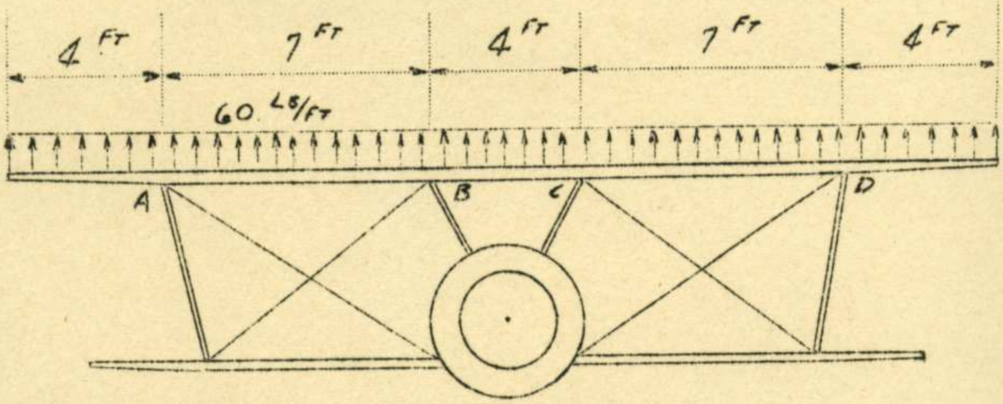


FIG 20D-2

21DO-1. Fig. 21DO-1 shows a 4-motored low-wing monoplane in flight. Each wing has four aluminum alloy spars with the cross-section at the root as shown in Fig. 21DO-2. Assume the loads to be evenly distributed among the 4 spars.

For the loading shown,

(a) Draw complete shear and moment diagrams.
(b) Determine the maximum fiber unit stress and state where it occurs. Assume constant cross-section for a spars, and neglect the effect of the rivet holes.
(c) Determine the shearing unit stress at a point 2 in. from the top on a section where the total shear is maximum.
(d) Determine the deflection the wing tip would have if the spars were of constant cross-section, and there were no rotation at the root (that is, assume the spars fixed at the fuselage) for,
    (a) The motor loads alone.
    (b) The distributed load alone.

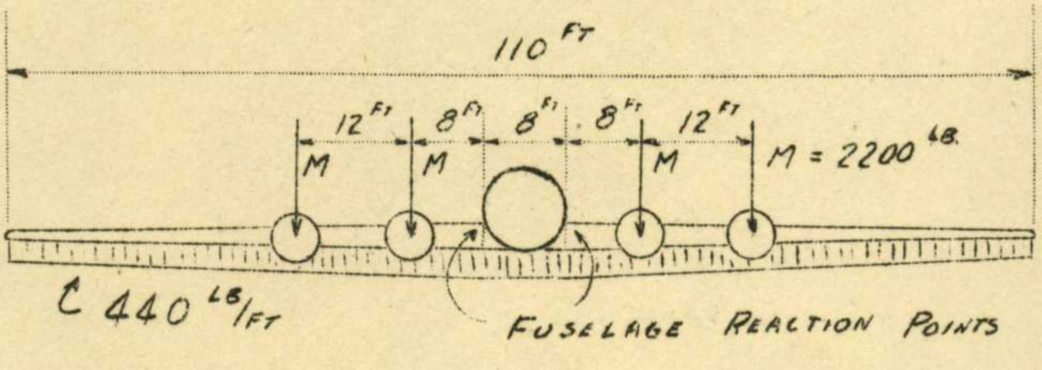


FIG. 21 DO-1

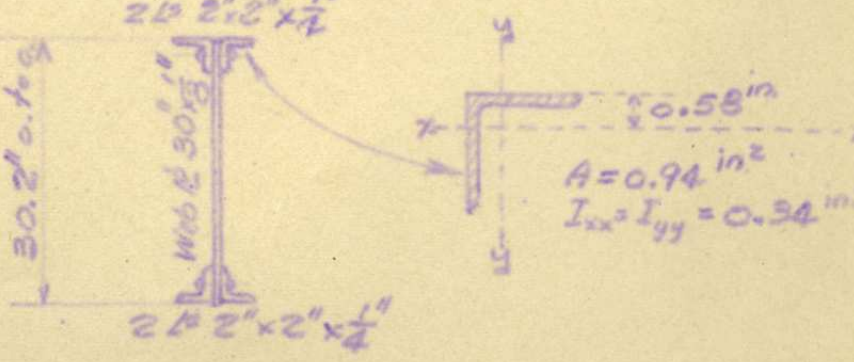


FIG. 21 DO-2

MECHANICS OF MATERIALS REVIEW PROBLEMS CURTISS-WRIGHT ENGINEERING
Course B-4 Seely Arts 33-41;116-131;58 CADETTES 21D-A-130

21D-1. (a). Draw complete shear and moment diagrams for the beam shown in Fig. 21D-1a.

(b). If the beam is a structural aluminum section, the properties of which are shown in Fig. 21D-1b, determine the maximum compressive fiber unit stress in the beam, and state where it occurs.

(c). Determine the maximum vertical shearing unit stress, and state where it occurs.

21D-2. Determine the maximum deflection of the beam in Fig. 21D-2.

21D-3. (a). Determine the reactions on the beam in Fig. 21D-3.

(b). Determine the shear just to the left of the center support.

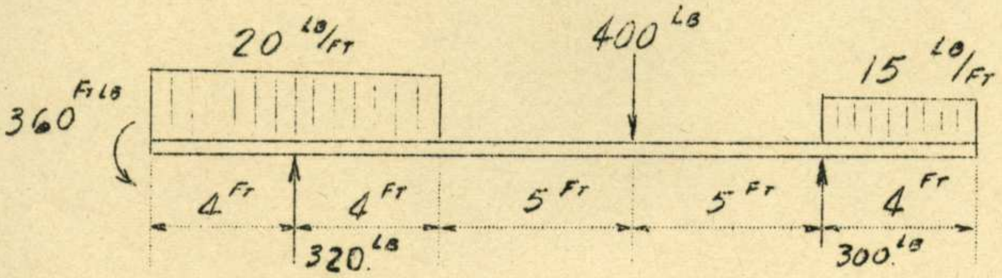


FIG 21 D1a

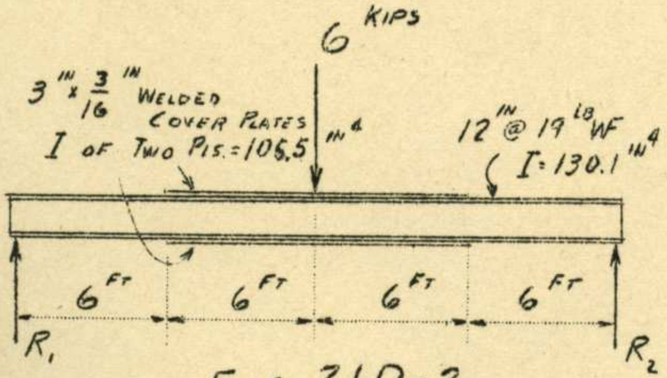


FIG. 21D-2

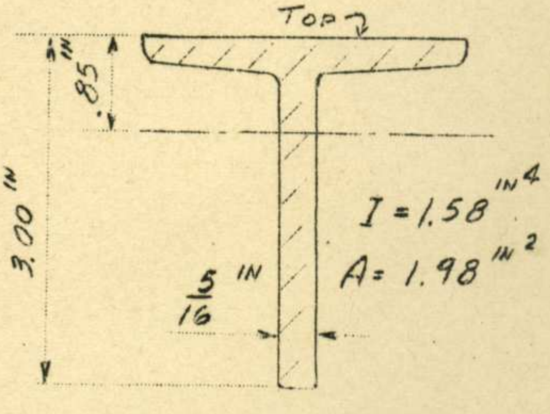


FIG. 21D1b

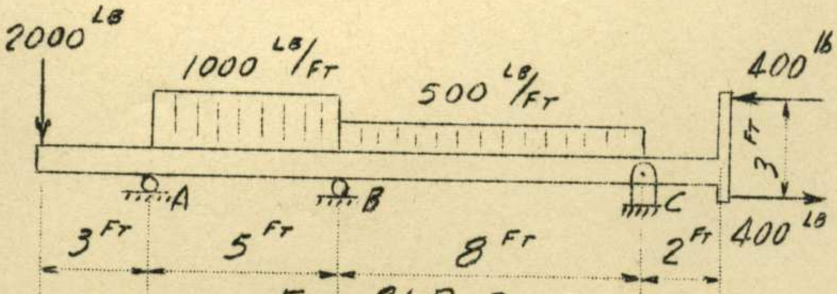


FIG 21 D-3

MECHANICS OF MATERIALS   QUIZ 2 (9437)   CURTISS-WRIGHT ENGINEERING
Course B-4   Seely: Art. 29-41, 58, 116-121, 128-131   CADETTES   22D-CZ3-131

Note: Show all work, including scratchwork, in blue book. Do not copy original questions in blue book. Return these questions with blue book.

1. Draw complete shear and moment diagrams for the beam indicated in Fig. 22D-1.
2. Determine (a) the maximum fiber unit stress and (b) the maximum shearing unit stress at section A in the wing rib indicated in Fig. 22D-2 for a uniform upward load of 48 lb. per ft. along the rib. Assume that the spars give the equivalent of simple supports at B and C.
3. Determine the left and center reactions of the beam in Fig. 22D-1 if an additional support is placed 4 ft. from the left end.
4. A cantilever beam of length L carries a concentrated load P at the free end. The moment of inertia of the outer half is I and of the inner half is 2 I. Determine the deflection of the free end in terms of P, L, E, and I.

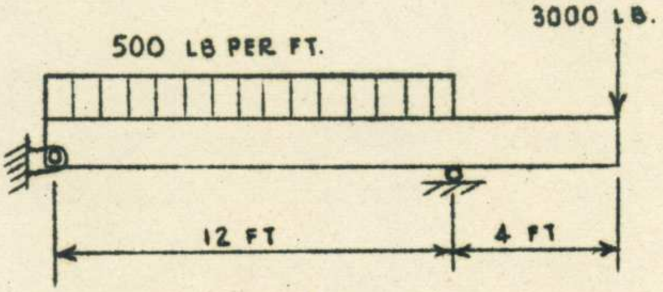


FIG. 22 D-1

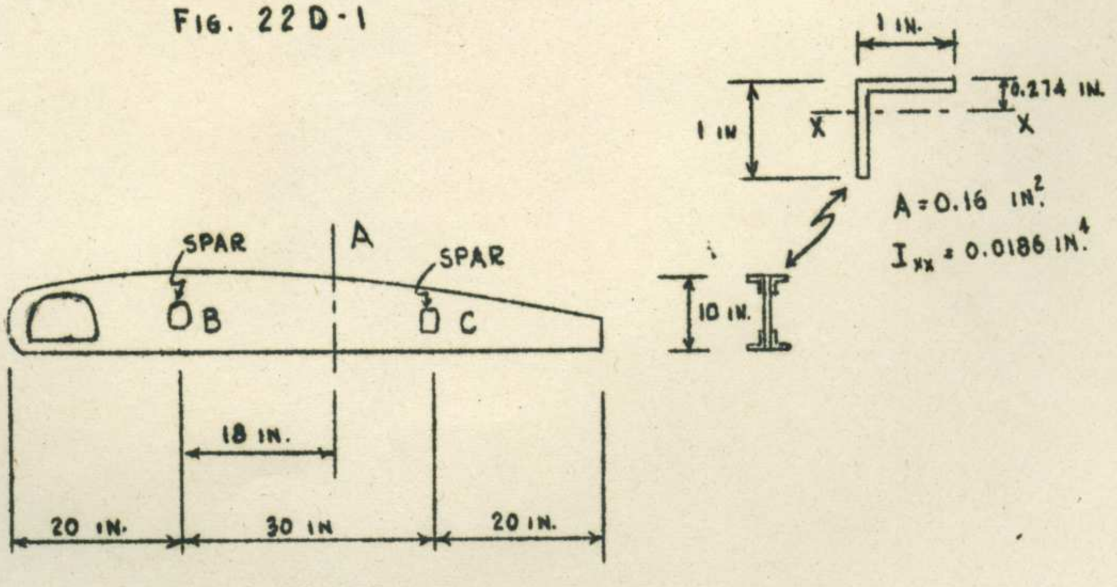


FIG. 22 D-2

CWP

MECHANICS OF MATERIALS
Course B-4

QUIZ 2 (10843)
Seely: Art. 29-41;
58; 116-121; 128-131

CURTISS-WRIGHT ENGINEERING
CADETTES 22D-HU1-132

Note: Show all work, including scratchwork, in blue book. Do not copy original questions in blue book. Return these questions with blue book.

1. Fig. 22D-1 shows the cross section of an 8 ft. beam simply supported at its ends. Determine the maximum concentrated load that the beam can carry at its mid-point if the shearing stress is not to exceed 300 p.s.i. and the fiber stress is not to exceed 5000 p.s.i. 5670 LB

2. Construct shear and moment diagrams for the horizontal portion AB of the beam shown in Fig. 22D-2. $M_{max} = -1800$ IN LB

$V_{max} = +80$ LB

3. The beam shown in Fig. 22D-3 is fixed at the right end and simply supported at A. A concentrated load of 200 LB is applied at the free end. Determine the reaction at A. R = 350 LB

4. A wing rib of a four engine airplane is shown in Fig. 22D-4(a). For convenience, assume a chordwise load distribution as shown in Fig. 22D-4(b). Determine the reaction of Spar A on the rib if the rib is assumed to be simply supported over the four spars. R = 453 LB.

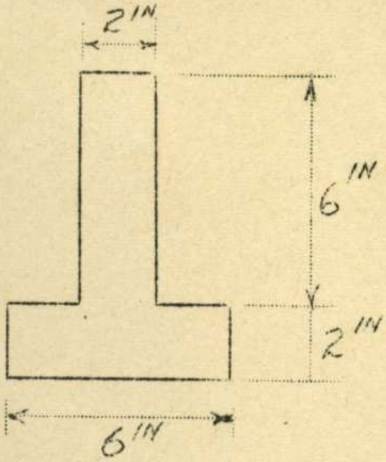


FIG. 22D-1

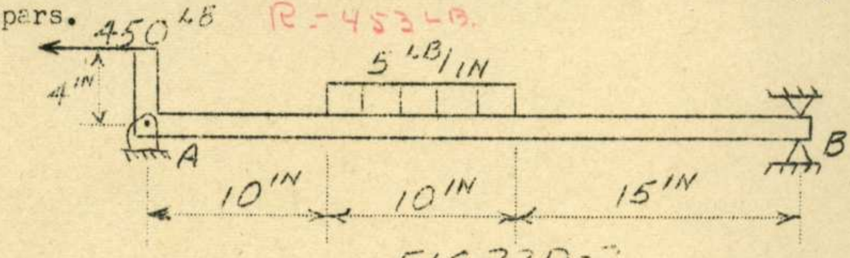


FIG. 22D-2

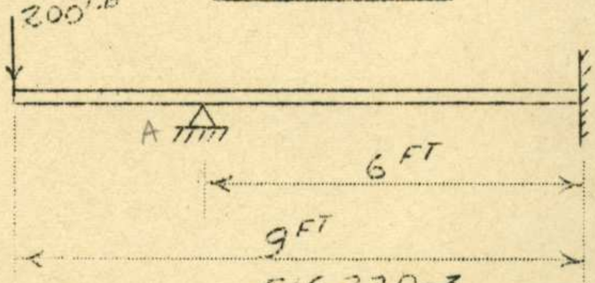


FIG. 22D-3

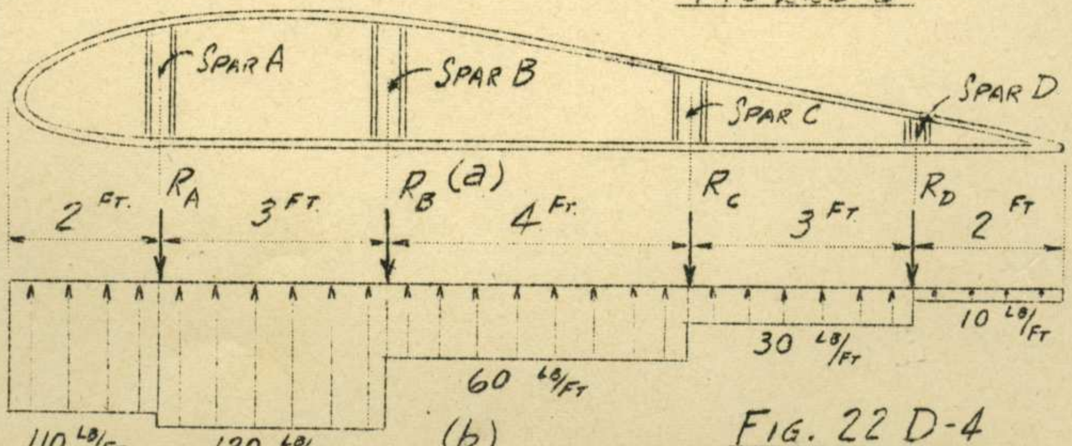


FIG. 22 D-4

MECHANICS OF MATERIALS
Course B-4

QUIZ 2 (10843)
Seely: Art. 29-41; 58;
116-121; 128-131

CURTISS-WRIGHT ENGINEERING
CADETTES 22D-HW2-133

Note: Show all work, including scratchwork, in blue book. Do not copy original questions in blue book. Return these questions with blue book.

1. A continuous beam is loaded as shown in Fig. 22D-1. Determine the reaction at A.

2. For the spruce wing spar shown in Fig. 22D-2, determine the maximum value of the uniformly distributed load if the maximum fiber unit stress is not to exceed 5000 p.s.i. and the maximum shearing unit stress is not to exceed 400 p.s.i.

3. Determine the deflection of the end C of the aluminum alloy cantilever beam in Fig. 22D-3. The moment of inertia of the beam between A and B is .47 in.^{4} and between B and C is .18 in.^{4}

4. Fig. 22D-4 shows a beam restrained at both ends. The moment at B is $\frac{1}{4}$ of the moment at A. Determine the magnitude of the moment at A in terms of P the concentrated load on the beam and L the length of the beam.

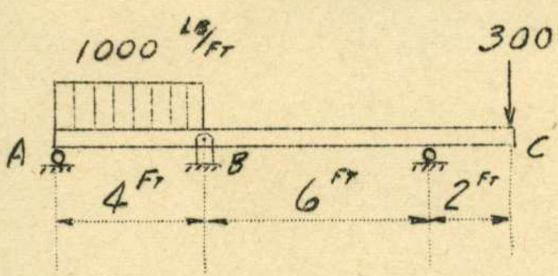


FIG. 22 D-1

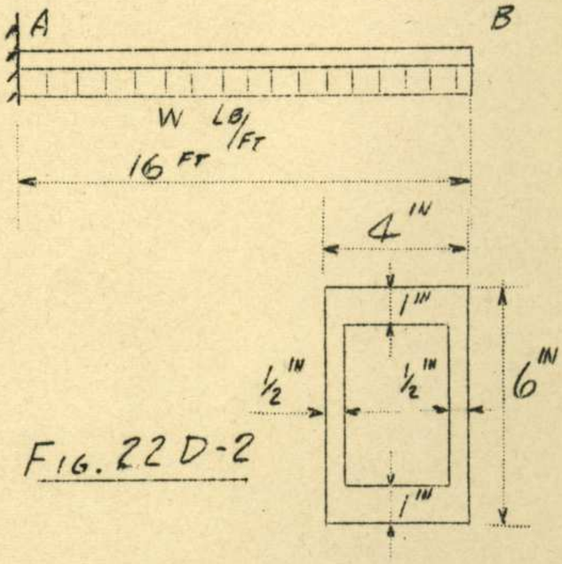


FIG. 22 D-2

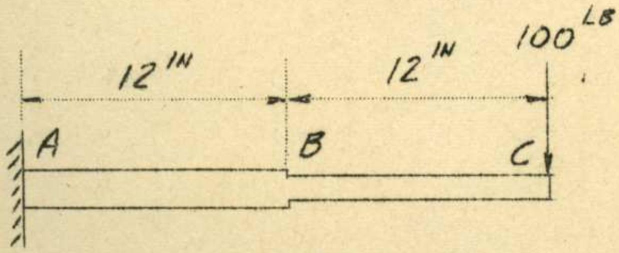


FIG. 22 D-3

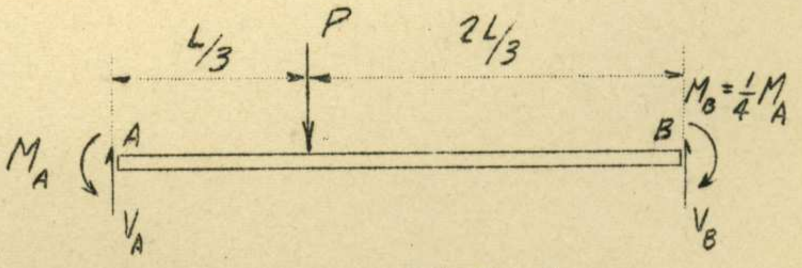


FIG. 22 D-4

MECHANICS OF MATERIALS
Course B-4

ASSIGNMENT SHEET
Seely: Resistance of Materials, 2nd. Ed.

CURTISS-WRIGHT ENGINEERING
CADETTES 22D-G-134

Week No.	Beginning	Peroid No.	Topics	Advance Assignment Articles	Advance Assignment Problems
8	9-7	22	Quiz	136, 23DO	438, 439
		23	Stresses in unsymmetrical bending		24DO-1
		24	Deflections in unsymmetrical bending	62-64	272, 274
9	9-14	25	Eccentric loads; combined axial and bending stresses	65	287, 288
		26	Eccentric loads on riveted connections	67-72	302, 305
		27	Euler columns	73	345, 306
10	9-21	28	Columns with end restraint	ANC-5 pp. 1-22 to 1-30	
		29	Short columns		
		30	Review		
11	9-28	31	Quiz		
		32	Review		
		33	Final Examination		

MECHANICS OF MATERIALS
Course B-4

SUPPLEMENTARY NOTES
Seely: Art. 132-139

CURTISS-WRIGHT ENGINEERING
CADETTES 23DO-N-135

UNSYMMETRICAL BENDING OF BEAMS
(Reference, Seely Chapter XV)

The flexure formula, $f_n = \frac{My}{I}$, has been applied thus far only to beams which have a symmetrical cross section, the axis of symmetry being perpendicular to the neutral axis. It has also been assumed that the moment due to the loads lies in the plane of symmetry. Under practical conditions it is often necessary to build beams which are not symmetrical, or which are not loaded symmetrically. Then, the neutral axis is not perpendicular to the plane of the loads.

Figure 1 indicates the cross section of an unsymmetrical beam. The plane of the loads is assumed as indicated and the neutral axis passes through the centroid of the section, but is not perpendicular to the plane of the load. An arbitrary set of x and y axes through the centroid are indicated for reference.

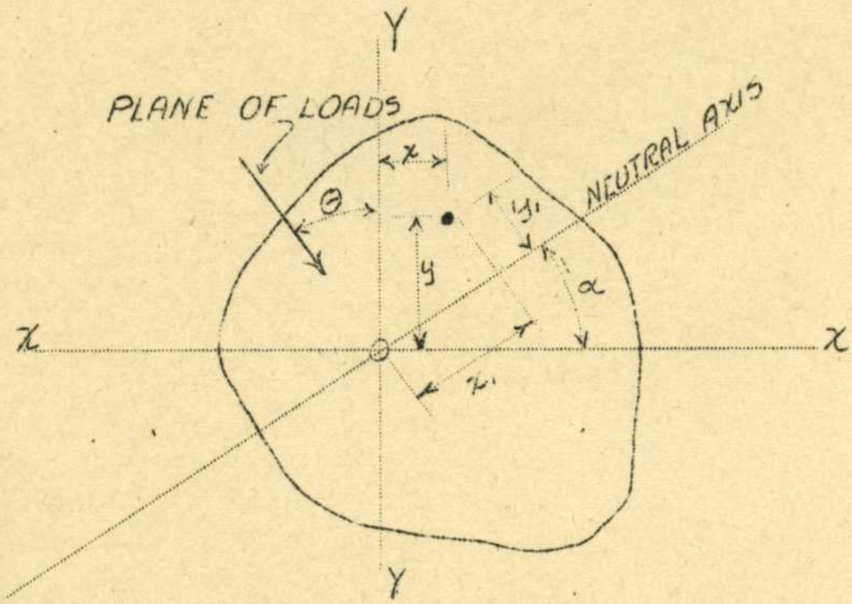


Figure 1

The flexural stress acting on a small area, a, at a distance y_1, from the neutral axis is f_1 and the stress at a distance c from the neutral axis is f. If a plane section before bending remains plane after bending, and if stress is proportional to strain

$$\frac{f_1}{y_1} = \frac{f}{c} \qquad (1)$$

$$f_1 = \frac{f}{c}(y_1)$$

The distance, y_1, may be expressed in terms of x and y. From Fig. 1

$$y = \frac{y_1}{\cos\alpha} + x\tan\alpha \qquad (2)$$

$$y_1 = y\cos\alpha - x\sin\alpha$$

Then
$$f_1 = \frac{f}{c} (y \cos\alpha - x \sin\alpha) \qquad (3)$$

The total force acting on the area a is $f_1(a)$ and the moment of the force about the x axis is

$$m_1 = f_1 \, a \, y$$
$$= \frac{f}{c} a \, (y^2 \cos\alpha - x \, y \sin\alpha) \qquad (4)$$

The moment of all of the forces acting on the cross section must be equal to the moment of all of the loads on the portion of the beam beyond the cross section.

$$M \cos\theta = \frac{f}{c} \cos\alpha \sum ay^2 - \frac{f}{c} \sin\alpha \sum axy \qquad (5)$$

If the x axis or the y axis is a <u>principal</u> axis, the term $\sum a \, x \, y$ is equal to zero[1] and

$$M \cos\theta = \frac{f}{c} \; I_x \cos\alpha \qquad (6)$$

since $\sum a \, y^2$ is the moment of inertia, I_x. Similarly, if moments are taken about the y axis

$$M \sin\theta = -\frac{f}{c} \; I_y \sin\alpha \qquad (7)$$

Equation (7) divided by Eq. (6) gives

$$\frac{\sin\theta}{\cos\theta} = \frac{-I_y \sin\alpha}{I_x \cos\alpha}$$

or

$$\tan\alpha = \frac{-I_x}{I_y} \tan\theta \qquad (8)$$

Therefore, if the plane of the loads is perpendicular to a <u>principal</u> axis θ = 0° and α = 0°. Then the neutral axis coincides with the x axis and Eq. (6) becomes

$$M = \frac{f \, I_x}{c} \qquad (9)$$

If the plane of the loads is not perpendicular to a <u>principal</u> axis but makes an angle θ with it, the flexural stresses may be evaluated from Eq. (7) after the angle α has been determined from Eq. (8).

However, a more common procedure is to resolve the moment into two components, one perpendicular to each of the principal axes, and determine the stress as

$$f = \frac{M_x \, y}{I_x} + \frac{M_y \, x}{I_y} \qquad (10)$$

in which M_x and M_y are the components of the moment
x and y are the coordinates of the point
I_x and I_y are the moments of inertia about the principal axes.

Illustrative Problems 436 and 437, page 329 of Seely show the procedure.

---

[1] The term $\Sigma \, a \, x \, y$ is called the <u>product of inertia</u>. It is equal to zero when the axes are <u>principal axes</u>. The principal axes at any point in an area are the axes at the point about which the moment of inertia ia a maximum or a minimum. An axis of symmetry is always a principal axis.

DIRECTION OF THE NEUTRAL AXIS

From Eq. (8) and Fig. 1, it is evident the neutral axis will be perpendicular to the plane of the loads ($\theta = \alpha$) only when the plane of the loads is perpendicular to a principal axis through the centroid ($\theta = 0^\circ$) or when $I_x = I_y$.

The angle between the plane of the loads and the neutral axis may be far different from 90° if the moments of inertia are appreciably different. For example, in a 1 in. by 6 in. rectangular cross section $I_x = 18$ in.^{4}, $I_y = 0.50$in.^{4} If $\theta = 1^\circ$

$$\tan\alpha = -36\ (.01746)$$
$$\alpha = 32^\circ\ 9'$$

DEFLECTIONS

The resultant deflection of a beam which is subjected to unymmetrical bending will not be in the direction of the loads. The most convenient method of determining the deflection is to resolve the loads into components parallel to the principal axes and evaluate the deflection for each component separately by an approporiate method (conjugate beam, for example). The two component deflections may be added vectorially. It will be found that the resultant deflection is perpendicular to the neutral axis.

THE SHEAR CENTER
(Reference, Seely, Chapter XIV)

The flexure formula, $f = M\,y/I$, was derived assuming that the only stress perpendicular to the cross section is due to bending; that there is no twisting which will induce additional stresses. For every straight beam there is a longitudinal axis which must contain the plane of the loads if the beam bends without twisting. This axis is called the <u>bending axis</u> of the beam. The intersection of the bending axis with a cross section is called the <u>shear center</u>. The shear center coincides with the centroid only if the cross section has two axes of symmetry; otherwise it is <u>not</u> at the centroid. (Note: Fig. 292 (a) and (b) in Seely are incorrect, Fig. 292 (c) and (d) are correct.)

The shear center of a cross section is found by assuming that the flexure formula is valid, and evaluating the shearing forces acting in the cross section. The intersection of the resultant shearing force with the neutral axis locates the shear center, which will often lie outside of the cross section. For example, assume that a channel with the web vertical is used as a cantilever beam with a load at the free end. At any distance, x, from the free end a tensile stress is developed in the upper flange and a compressive stress in the lower flange. At a slightly greater distance, x + Δ x, from the free end similar, but slightly greater stresses are developed.

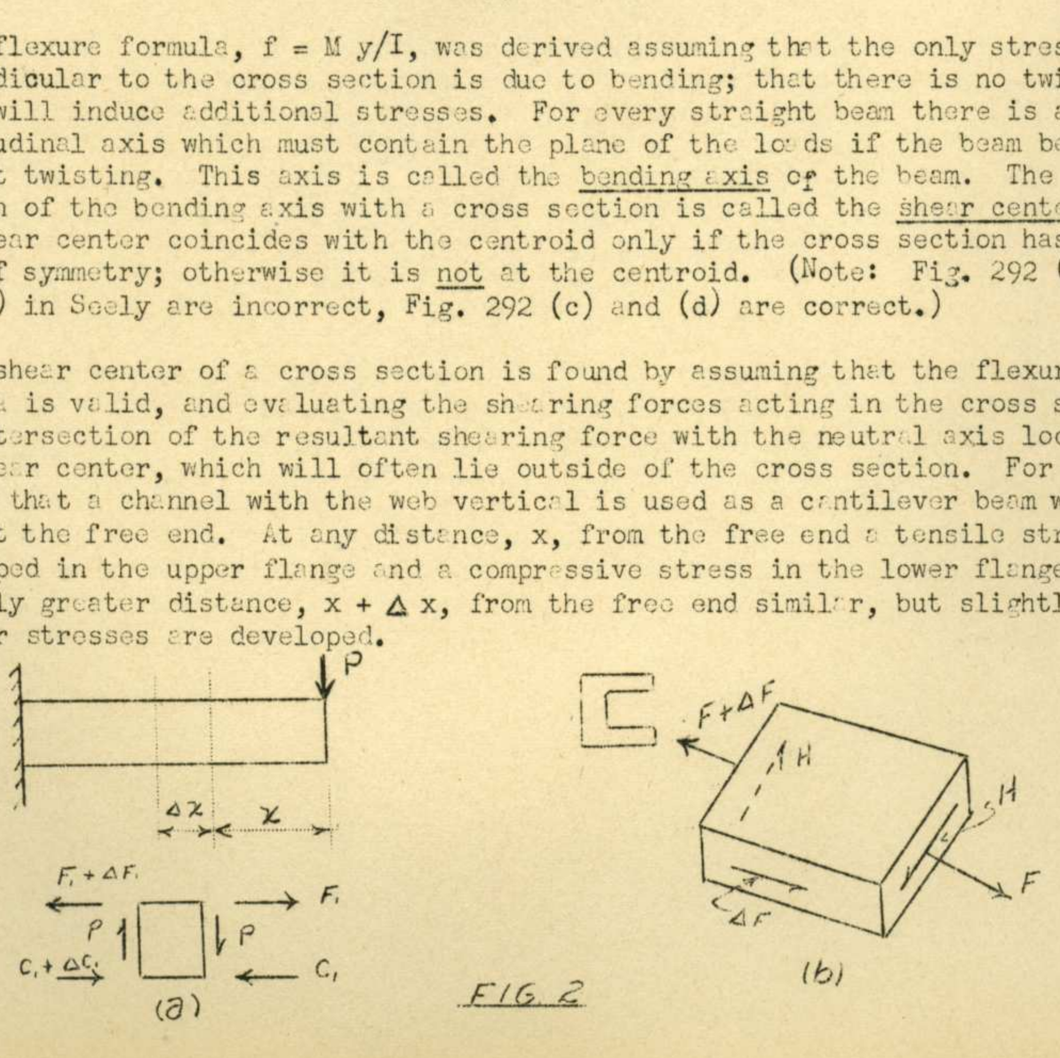


FIG 2

If a free-body diagram of the section of the upper flange over the length x is drawn as shown in Fig. 2(b), it will have a force F on the right end and a force F $+\Delta$ F on the left end. A shearing force Δ F must act along the junction of web and flange as shown, to satisfy the force equation of equilibrium in the longitudinal direction. The shearing force Δ F and the resultant of the tensions form a couple which is balanced by a couple H (Δx) as indicated, the force H being a shearing force also. In the bottom flange a similar shearing force in the opposite direction will be induced as indicated in Fig. 3(a). The resultant of the two horizontal shearing forces (which form a couple) and the vertical shearing force P is a single force P_1 as indicated in Fig. 3(b). The intersection of P_1 with the neutral axis of the channel locates the shear center.

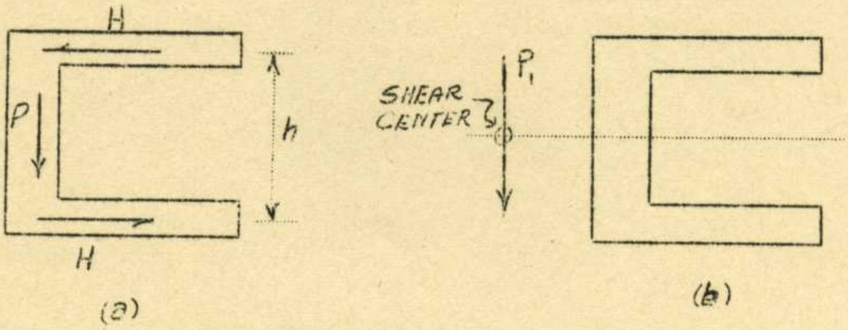


Figure 3

If the entire channel is to bend without twisting the load P must lie in a plane which passes through the shear center of every cross section. If the load does not lie in that plane, the beam will twist and stresses higher than those given by $f = M y/I$ will be developed.

PROBLEMS

24DO-1. A single spruce spar 10 in. deep 4 in. wide and 15 ft. long carries the wing load in a monoplane. The 4 in. dimension is parallel to the wing chord. Determine the maximum fiber stress in the spar when the angle of attack is 12°, assuming that the lift is a uniformly distributed load of 150 lb. per ft., and the drag is a uniformly distributed load of 10 lb. per ft.

24DO-2. Determine the direction of the neutral axis and the deflection of the tip of the spar of Prob. 24DO-1.

23D-1. A section of streamline tubing having the properties indicated in Fig. 23D-1 is used to suspend an auxillary gasoline tank from the wing of an airplane. If, under a certain wind condition, the resultant drag on the tank is 50 lb. at an angle of 30° with the major axis 24 in. below the fixed end of the tubing, determine the stresses at each end of each of the axes, and indicate the direction of the neutral axis. Neglect stresses due to direct load.

23D-2. A 2 in. by 2 in. by $\frac{1}{4}$ in. structural aluminum angle is used as a cantilever beam. Determine the maximum load which may be applied 10 ft. from the fixed end if the maximum flexural stress is not to exceed 20,000 p.s.i. The load is applied parallel to one of the legs of the angle, $A = 0.94$ in.^{2}, $\bar{x} = \bar{y} = 0.58$in. $r_{min.} = 0.39$ in. $r_x = r_y = 0.60$ in.

23D-3. The Z-section shown in Fig. 23D-3 is to be used as a simply supported beam on a span of 6 ft., and is to carry a concentrated load of 1200 lb. in the direction of the YY axis at a distance of 2 ft. from one end. Determine the direction of the neutral axis.

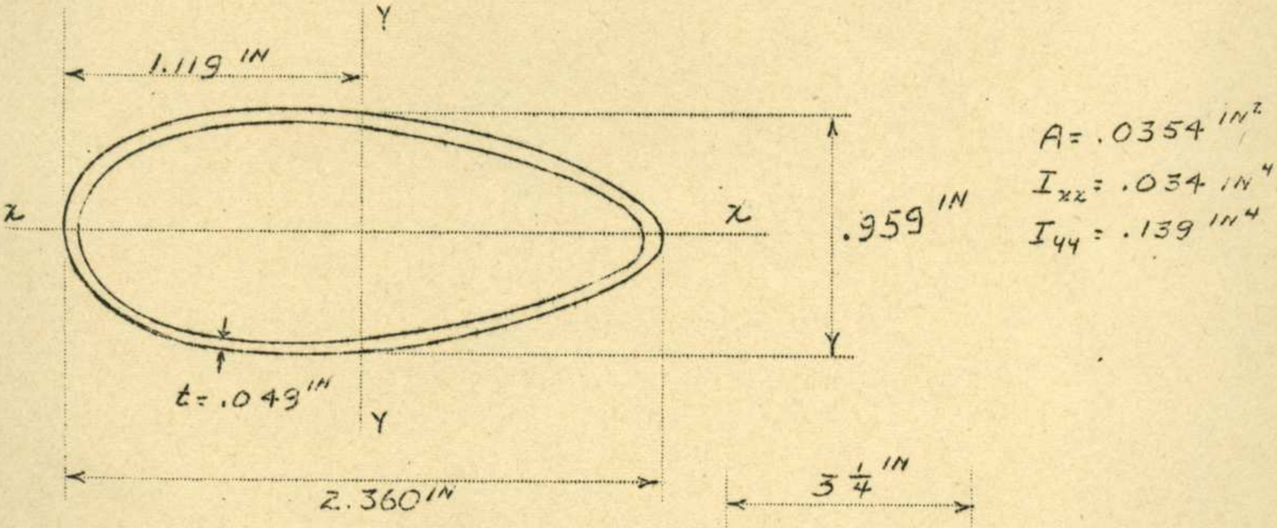
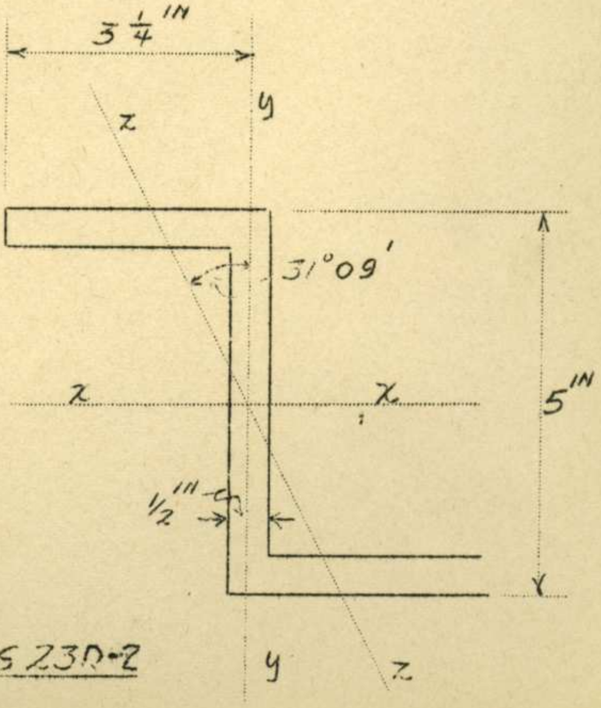


FIG. 23D-1

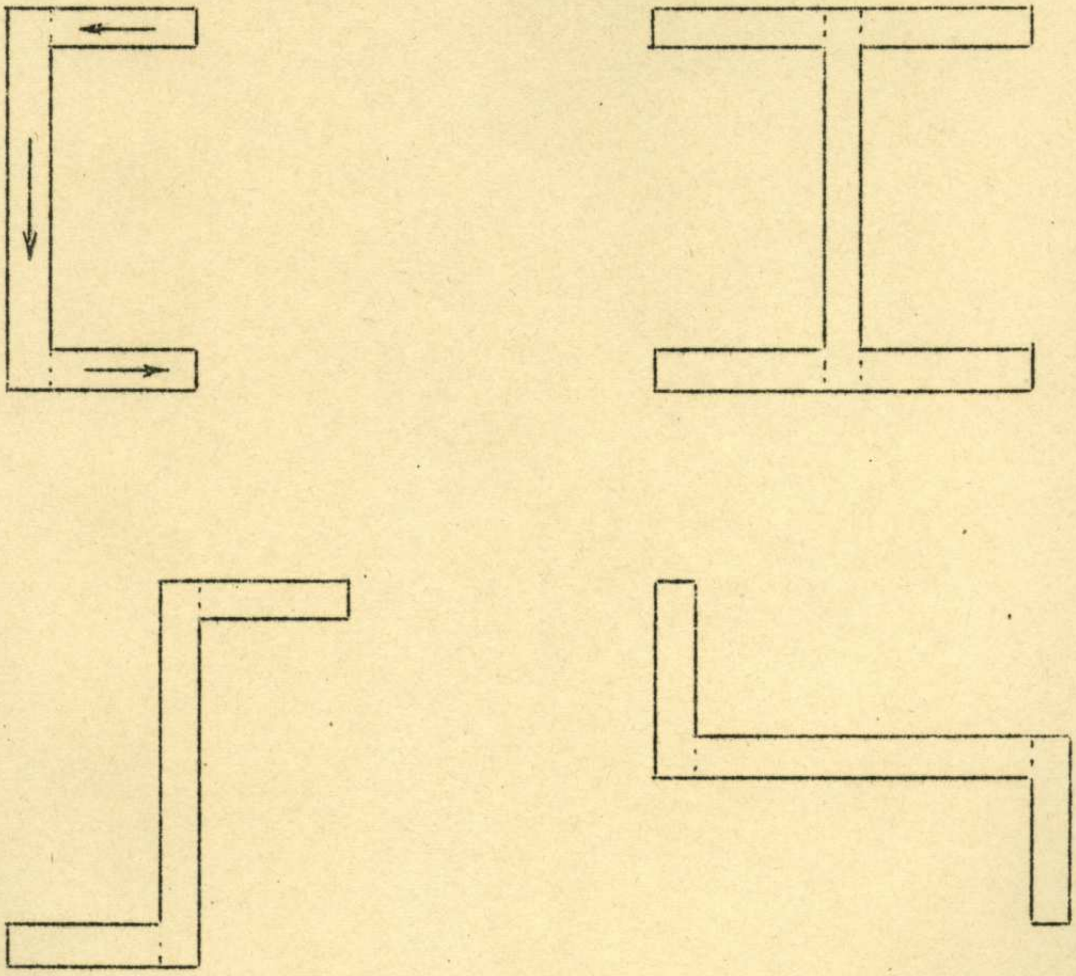


A = 5.27 IN²
r_xx = 1.91 IN
r_yy = 1.29 IN
r_zz = .73 IN

FIG 23D-2

24D-1. Each of the sections in Fig. 24D-1 represents the cross section of a cantilever beam carrying a vertical concentrated load through the shear center at the free end. Indicate the direction of the shearing force, if any, developed parallel to the long side in each rectangle of the section, as illustrated for the channel.

24D-2. Determine the deflection of the end of the streamline tubing in Problem 23D-1.



TYPICAL SECTIONS A-A

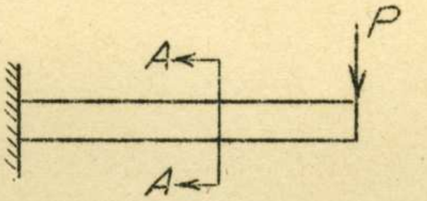


FIG. 24D-1

25D-1. The static reaction, R, on the tail wheel of Fig. 25D-1 is 500 lb. Determine the maximum stress in the landing wheel strut for a load factor of 4. Neglect the deflection of the assembly.

25D-2. Fig. 25D-2 shows the pilot's seat of an airplane. The section A-A consists of two 1 in. diameter alloy steel tubes $\frac{3}{32}$ in. thick. Determine the maximum vertical compressive stress in section A-A and state where it occurs, if the plane is travelling in horizontal level flight with an acceleration of 10 ft./ sec.^{2}. Assume that the pilot weighs 180 lb. and that the resultant force of the pilot on the seat passes through point B.

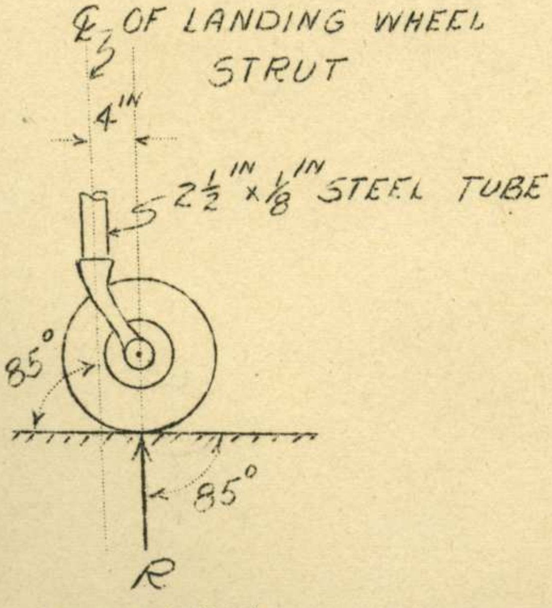


FIG. 25D-1

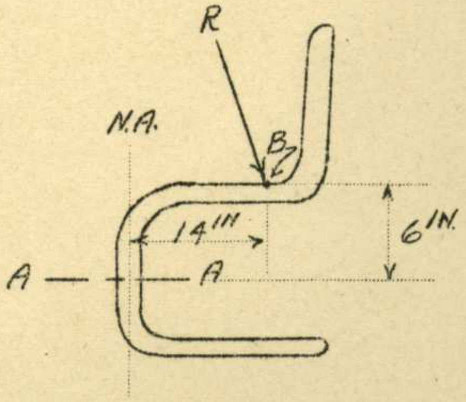


FIG. 25D-2

26D-1. A gusset plate carrying a load of 1800 lb. is held by three ½-in. diameter rivets as shown in Fig. 26D-1.

(a). Which rivet carries the greatest load?

(b). Determine the average shearing unit stress in the rivet carrying the greatest load.

26D-2. Fig. 26D-2 shows a fitting for a wing spar and the pin reaction components acting on the fitting. Determine:

(a). Which bolt carries the greatest load, and determine the magnitude of the load it carries.

(b). Which bolt carries the least load, and determine the magnitude of the load.

(c). The minimum diameter of bolt necessary if the allowable unit shearing stress is 12,000 p.s.i.
(Note: all bolts are to be the same size)

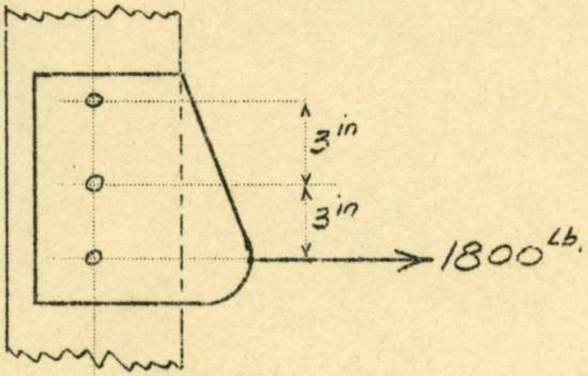


FIG. 26D-1

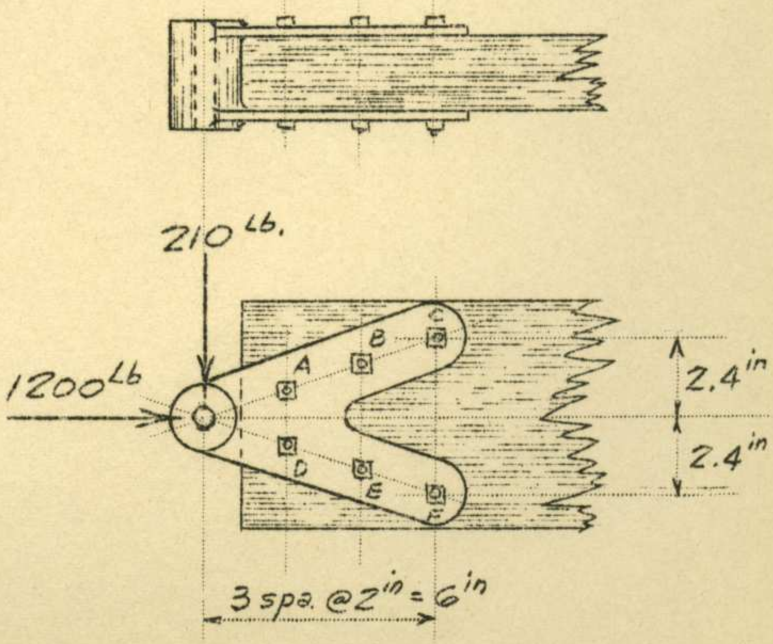


FIG. 26D-2

27D-1. A spruce column with a rectangular cross section 1 in. by 2 in. is 40 in. long. Determine the slenderness ratio and the load the column will carry if the ends are assumed to be pinned.

27D-2. A steel tube with an outside diameter of 1.000 in. and an inside diameter of 0.609 in. is to be used as a piston rod for operating a bomb door. Determine the maximum length of tube which will support the design load of 7560 lb. Assume pin ends.