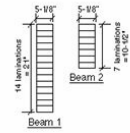


Rich's General Structural Study Notes:

Kaplan – Test Bank Questions

Two glued laminated beams with the same modulus of elasticity are shown below. For a given load and span, beam 1 will deflect 1/4 inch. For the same load and span, how much will beam 2 deflect?



- A. 1/4 inch
- B. 1 inch
- C. 1 1/4 inches
- D. 2 inches

The answer is 2 INCHES. The deflection of a beam

$$(\Delta)$$

is inversely proportional to its moment of inertia (I). The value of I for a rectangular beam is equal to

$$bd^3/12.$$

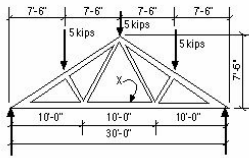
Since the load, span, and beam width are the same for both beams, the only variable is depth d.

$$\Delta_1 \sim 1/(d_1)^3 \text{ and } \Delta_2 \sim 1/(d_2)^3$$

$$\Delta_1 (d_1)^3 = \Delta_2 (d_2)^3$$

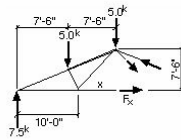
$$\Delta_2 = \Delta_1 (d_1/d_2)^3 = 0.25 (21/10.5)^3 = 0.25 (2)^3 = 0.25 \times 8 = 2 \text{ inches}$$

For the truss shown below, what is the tension in member x?



- A. 5.0 kips
- B. 7.5 kips
- C. 10.0 kips
- D. 15.0 kips

Correct!
The answer is 10.0 KIPS. The simplest way to solve this truss problem is to cut a section through member x and draw a free body diagram, as shown below.



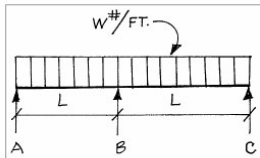
The left and right reactions are each equal to half the total load on the truss, or $(5 + 5 + 5) / 2 = 7.5$ kips. We take moments about the top of the truss.

$$\sum M = 0$$

$$7.5 \text{ kips}(15 \text{ ft}) - 5 \text{ kips}(7.5 \text{ ft}) = 0$$

$$F_x = [7.5(15) - 5(7.5)] / 7.5 = 10 \text{ kips}$$

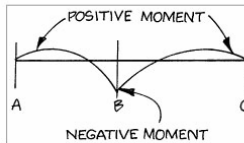
Select the INCORRECT statement concerning the continuous beam shown.



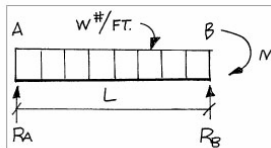
- A. There is positive moment in spans AB and BC.
- B. The moment over support B is negative.
- C. The reaction at A and C is less than $wL/2$.
- D. The reaction at B is less than wL .

D. The reaction at B is less than wL .

Correct!
A continuous beam, as the name suggests, is one which is continuous over at least one interior support. The moment in a continuous beam is positive (compression at the top, tension at the bottom) between supports and negative (tension at the top, compression at the bottom) over the supports, as shown in the moment diagram below.



Therefore, statements A and B are correct. To understand the reaction, we isolate span AB.



Since the moment over support B is negative (tension at the top), it acts clockwise on the free body as shown.

$$\sum M_B = 0$$

$$(R_A \times L) - wL \times L/2 + M = 0$$

$$R_A = wL/2 - M/L$$

Thus, the reaction at A is less than $wL/2$. This is similarly true of the reaction at C, and choice C is therefore correct.

$$\sum V = 0$$

$$R_A + R_B = wL$$

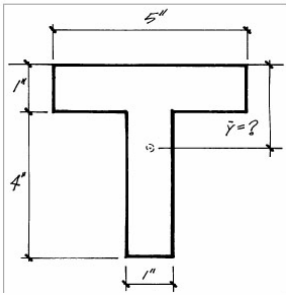
$$R_B = wL - (wL/2 - M/L)$$

$$= wL/2 + M/L$$

The total reaction at B is equal to R_B for span AB plus the identical value of R_B for span BC
 $= 2R_B = 2(wL/2 + M/L) = wL + 2M/L$

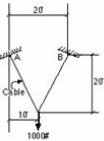
The reaction at B is therefore greater than wL , and D is the incorrect statement we are looking for. While this may be more time-consuming than most exam questions, candidates should expect some questions of this type.

Find the distance y to the centroid of the area shown. $Y =$



- A. 1.61"
- B. 3.39"
- C. 1.75"
- D. 1.89"

A cable is suspended between points A and B and supports a load of 1000#, as shown below. What is the tension in the cable?



- A. 559#
- B. 1000#
- C. 1118#
- D. 2000#

A steel column supporting an ultimate load of 685 kips is to bear on a concrete pedestal which has a bearing strength of 4760 psi. What is the minimum size base plate which may be used?

- A. 10" x 10"
- B. 12" x 12"
- C. 14" x 14"
- D. 16" x 16"

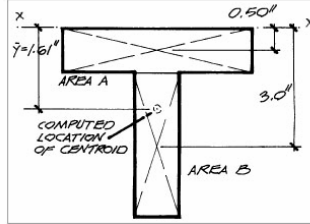
A continuous beam has a maximum negative moment of 600 ft-kips and a maximum positive of 350 ft-kips. If the beam is of ASTM A36 steel and is supported laterally, what is its required section modulus?

- A. 117 in³
- B. 175 in³
- C. 200 in³
- D. 300 in³

The columns of a three-story building are spaced at 24 feet o.c. in one direction and 28 feet o.c. in the other direction. The loads are as shown below. Neglecting the weight of the column and any live load reduction, what is the smallest pad footing which may be used? The allowable soil bearing value is 4,000 pounds per square foot.

Roof dead load – 30 lbs. per square foot
 Roof live load – 20 lbs. per square foot
 Floor dead load – 80 lbs. per square foot
 Floor live load – 100 lbs. per square foot

- A. 5'8" x 5'8"
- B. 6'8" x 6'8"
- C. 7'4" x 8'8"
- D. 8'4" x 8'4"

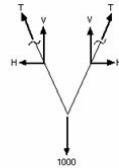


The area is divided into two parts, A and B, as shown above. Calculate the area of each part and the static moment of each part about axis $x-x$, the top of the area.

Part	Area	y	Area xy
A	$5 \times 1 = 5.0$	0.50	$5.0 \times 0.50 = 2.5$
B	$4 \times 1 = 4.0$	3.0	$4.0 \times 3.0 = 12.0$
Total	9.0		14.5

$y =$ the distance from axis $x-x$ to the centroid of the area = $14.5/9.0 = 1.61"$ (correct answer A).

The answer is 559#. To solve this problem, you need to know the basic equations of equilibrium and apply the Pythagorean theorem. The 1000# load is supported by tension T in the cable, as shown below.



From $\Sigma V = 0$, $V + V = 1000\#$, from which $V = 500\#$. The ratio of the horizontal component H of the cable tension to the vertical component V is equal to the ratio of the horizontal component of the cable length (10 ft) to the vertical component (20 ft), or 10/20. Therefore, $H = (10/20) \times V = 1/2 \times 500\# = 250\#$. $T = \sqrt{(500^2 + 250^2) = 559\#}$ (correct answer A).

A steel column supporting an ultimate load of 685 kips is to bear on a concrete pedestal which has a bearing strength of 4760 psi. What is the minimum size base plate which may be used?

- A. 10" x 10"
- B. 12" x 12"
- C. 14" x 14"
- D. 16" x 16"

Correct!
 The answer is 12" x 12". The load is transferred from the steel column to the base plate, and then from the base plate to the concrete directly by bearing. The required area of the base plate is equal to the load divided by the bearing strength, or $685,000\# / 4760 \text{ psi} = 143.9$ square inches. If we use a square base plate, the dimension of each side must be at least the square root of 143.9 = 12 inches.

The answer is D. Steel beams are designed to resist the maximum bending moment to which they are subjected, whether positive or negative. To determine the required section modulus S, we use the basic flexure formula

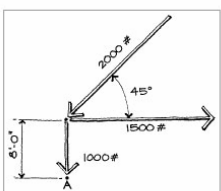
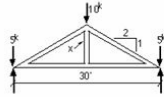

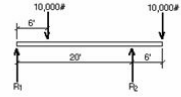
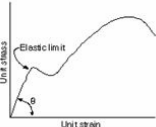
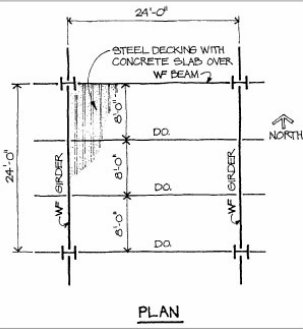
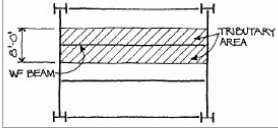
$$S = M/F_b$$

In this case, the maximum moment M is the negative moment of 600 ft-kips.

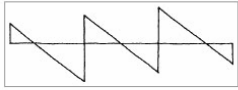
F_b is the allowable bending stress, which is 0.66 times the yield stress F_y , which is 36 ksi for ASTM A36 steel.

F_b is therefore $0.66 \times 36 = 24$ ksi. So the required section modulus $S = M/F_b = (600 \text{ ft-kips} \times 12 \text{ inches/ft}) / 24 \text{ ksi} = 300 \text{ in}^3$

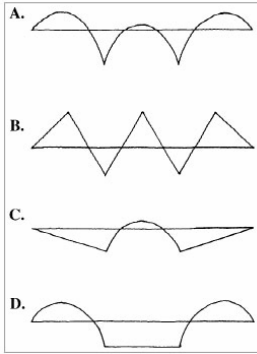
The answer is 8'4" x 8'4". The question involves the concept of tributary area, which is the area of each floor or roof which contributes load to a member. In this case, the columns are 24 feet apart in one direction and 28 feet apart in the other direction. The area tributary to each column is therefore 24 feet by 28 feet, or 672 square feet for each floor and the roof. The roof load to each column is 672 square feet x (30 + 20) lbs. per square foot = 33,600 lbs. The floor load to each column is 672 square feet x (80 + 100) lbs. per square foot = 120,960 lbs. for each floor. Since this is a three-story building, there are two supported floors plus the roof, making a total load of $33,600 + 120,960 + 120,960 = 275,520$ lbs. The required footing area is $275,520 \text{ lbs} / 4,000 \text{ lbs. per square foot} = 68.88$ square feet. Column pad footings are generally square, so we compute the square root of 68.88 (using a calculator, or course) = 8.30 feet. The minimum size pad is therefore 8'4" x 8'4" (answer D). For simplicity, we are told in this question to neglect the column weight and any live load reduction. In actual practice, these would be considered, but the calculation would be similar.

<p>What is the moment about point A of the three forces shown below?</p>  <p> <input type="radio"/> A. 4,000# <input checked="" type="radio"/> B. 688# <input type="radio"/> C. 12,000# <input type="radio"/> D. 23,312# </p>	<p> <input type="radio"/> A. 4,000# <input checked="" type="radio"/> B. 688# <input type="radio"/> C. 12,000# <input type="radio"/> D. 23,312# </p> <p>Correct! Each force produces a moment about point A equal to the magnitude of the force multiplied by its distance from point A. The total moment is equal to the algebraic sum of the moments caused by all the forces. The 1,500# horizontal force produces a clockwise moment equal to $1,500 \times 8$ feet = 12,000#. The 1,000# vertical force produces no moment, since its line of action passes through point A. The moment caused by the 2,000# force at 45° is determined by resolving the force into its vertical and horizontal components. The vertical component is $2,000 \sin 45^\circ = 1,414\#$, and the horizontal component is $2,000 \cos 45^\circ = 1,414\#$. The vertical component causes no moment, since its line of action passes through point A. The horizontal component produces a counterclockwise moment of $1,414 \times 8 = 11,312\#$. The total moment is the algebraic sum of the moments = $12,000 - 11,312 = 688\#$ clockwise (answer B).</p>
<p>What is the internal stress in member x of the truss shown below?</p>  <p> <input type="radio"/> A. 10 kips compression <input type="radio"/> B. 5 kips compression <input type="radio"/> C. 2.5 kips compression <input type="radio"/> D. Zero </p>	<p>The correct answer is ZERO. To solve this problem, we isolate the joint where member x intersects the bottom chord.</p>  <p>We apply the basic equation $\Sigma V = 0$</p> <p>Since the only vertical force acting at the joint is the stress in member x, $(F_x) + F_x = 0$</p> <p>The stress in member x is zero.</p>
<p>A beam supports the loads shown below. What is the value of reaction R_2, neglecting the weight of the beam?</p>  <p> <input type="radio"/> A. 4000# <input type="radio"/> B. 6000# <input type="radio"/> C. 16,000# <input type="radio"/> D. 20,000# </p>	<p>The answer is 16,000#. Candidates should be able to determine the reactions of any statically determinate beam subject to any load. To determine the value of reaction R_2,</p> <p>we take moments about R_1.</p> $\Sigma M_R = 0$ $+(10,000\# \times 6 \text{ ft}) + (10,000\#)(20 + 6)\text{ft} - R_2(20 \text{ ft}) = 0$ $R_2 = (60,000 + 260,000) / 20 = 16,000\#$
<p>A typical stress-strain diagram for steel is shown below. What is the tangent of angle θ called?</p>  <p> <input type="radio"/> A. Moment of inertia <input type="radio"/> B. Modulus of elasticity <input type="radio"/> C. Section modulus <input type="radio"/> D. Modulus of rupture </p>	<p>The answer is MODULUS OF ELASTICITY. The stress-strain diagram shown, which is typical for steel, shows that the ratio of unit stress to unit strain, which is the tangent of angle θ, is constant up to the elastic limit. This ratio is called the modulus of elasticity (correct answer B). Moment of inertia (A) and section modulus (C) are properties of the specific member, not of its material. Moment of inertia is a measure of a member's resistance to deflection, and section modulus determines the resistance of a member to bending moment. The modulus of rupture (D) is the calculated value of flexural stress just before rupture.</p>
<p>The typical interior bay of a building is 24 feet by 24 feet in plan and is framed with steel beams and girders as shown in the following illustration. The floor live load is 100 psf, and the dead load is 60 psf. What is the maximum moment in a typical east-west beam?</p>  <p> <input type="radio"/> A. 11,520 ft.-lbs. <input type="radio"/> B. 57,600 ft.-lbs. <input checked="" type="radio"/> C. 92,160 ft.-lbs. <input type="radio"/> D. 276,480 ft.-lbs. </p>	<p> <input type="radio"/> A. 11,520 ft.-lbs. <input type="radio"/> B. 57,600 ft.-lbs. <input checked="" type="radio"/> C. 92,160 ft.-lbs. <input type="radio"/> D. 276,480 ft.-lbs. </p> <p>Correct! Questions involving the concept of "tributary area" sometimes appear on the exam. In this case, the area tributary to each east-west beam extends halfway to each adjacent beam, as shown hatched in the diagram above. In other words, each east-west beam supports 8 feet of load. Therefore, the uniform load supported by each east-west beam is $8(100 + 60) = 1,280$ lbs. per ft.</p> 

A three-span continuous beam supporting a uniformly distributed load has a shear diagram as shown below.

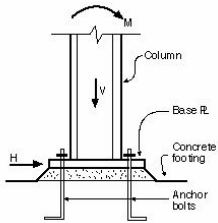


Which of the following is the corresponding moment diagram?



The anchor bolts shown below are used to resist

- I. Moment M
- II. Horizontal force H
- III. Vertical load V



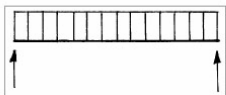
- A. I and II
- B. II and III
- C. I and III
- D. I, II, and III

Candidates should understand the concepts of shear and moment diagrams, and may expect to see exam questions which test that understanding. For a beam supporting a uniform load, the moment diagram is parabolic, which rules out B, C, and D, all of which have straight-line portions. The correct answer is A.

The correct answer is I AND II. Moment M is resisted by tension in the anchor bolts and compression on the base plate. Horizontal force H is resisted by shear in the anchor bolts. Vertical load V is resisted by bearing on the concrete footing, not by the anchor bolts.

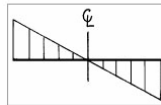
For the simple beam shown, where is the horizontal shear stress greatest?

- I. At midspan
- II. Next to the supports
- III. At the outer fibers of the beam cross-section
- IV. At the neutral axis of the beam cross-section

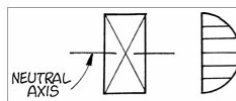


- A. I and III
- B. I and IV
- C. II and III
- D. II and IV

The shear diagram for the beam in this question is:



Thus, the shear stress is maximum next to the supports (II). The variation in shear stress in the beam cross-section is:



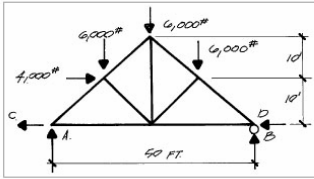
Therefore, within the beam cross-section, the shear stress is maximum at the neutral axis (IV).

A uniform roof live load of 20 pounds per square foot corresponds to a depth of how many inches of rain water on the roof? Water weighs 62.4 pounds per cubic foot.

- A. 1"
- B. 2"
- C. 4"
- D. 6"

The answer is 4". Roof live load is produced by workers and materials during maintenance, as well as by possible buildup of rain water. Water weighs 62.4 pounds per cubic foot, or $62.4 / 12 = 5.2$ pounds per square foot per inch of depth of water. So a live load of 20 pounds per square foot corresponds to a depth of $20 / 5.2 = 3.85$ inches. The answer closest to this value is C, 4 inches.

What are the reactions A, B, C, and D on the roof truss shown supporting the vertical and horizontal loads indicated? The truss is free to roll at the right support only.



- A. A = 9,800#, B = 8,200#, C = 4,000#, D = 0
- B. A = 8,200#, B = 9,800#, C = 4,000#, D = 0
- C. A = 8,200#, B = 9,800#, C = 0, D = 4,000#
- D. A = 9,000#, B = 9,000#, C = 4,000#, D = 0

This problem involves basic statics, and the methods used in its solution are fundamental. If you have difficulty solving the problem or following our solution, you should spend time reviewing statics. Since the truss is free to roll at the right support, no horizontal reaction is possible there. Therefore, reaction D is zero.

$$\begin{aligned} \sum H &= 0 \\ 4,000 - C - D &= 0 \\ 4,000 - C - 0 &= 0 \\ C &= 4,000\# \end{aligned}$$

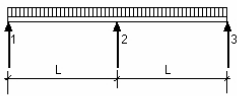
To solve for reaction B, take moments about the left support.

$$\begin{aligned} \sum M &= 0 \\ 6,000(50/4) + 6,000(50/2) \\ + 6,000(3 \times 50/4) + 4,000(10) - 50B &= 0 \\ 50B &= 6,000(12.5 + 25 + 37.5) + 40,000 \\ B &= (450,000 + 40,000)/50 \\ B &= 9,800\# \\ \sum V &= 0 \\ A + B - 6,000 - 6,000 &= 0 \\ A + B &= 18,000 \\ A + 9,800 &= 18,000 \\ A &= 18,000 - 9,800 = 8,200\# \end{aligned}$$

Summarizing, A = 8,200#, B = 9,800#, C = 4,000#, D = 0 The correct answer is B.

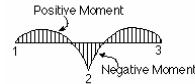
The two-span continuous beam shown below supports a uniform load. Which of the following statements are correct?

- I. The moment over support 2 is negative
- II. There is no moment at supports 1 and 3
- III. The moment in each span is positive across the entire span



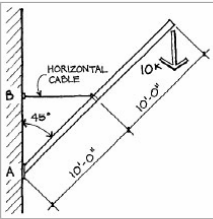
- A. I and II
- B. II and III
- C. I and III
- D. I, II, and III

The answer is I AND II. The two-span continuous beam in this question has a moment diagram which looks like this:



There is zero moment at end supports 1 and 3 (II) and negative moment over interior support 2 (I). The moment in spans 1-2 and 2-3 varies from positive to negative (III is incorrect). Since only statements I and II are correct, A is the correct answer.

A rigid bar 20 feet long supports a 10 kip load at its end as shown. Neglecting the weight of the bar, what is the tensile force in the horizontal cable?

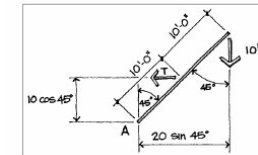


- A. 14.1 kips tension
- B. 20 kips compression
- C. 10 kips tension
- D. 20 kips tension

This is a problem in basic statics which can be solved by taking moments about point A. (See illustration following.)

$$\begin{aligned} \sum M_A &= 0 \\ 10 \times 20 \sin 45^\circ \times T(10 \cos 45^\circ) &= 0 \\ T &= (20 \sin 45^\circ)(\cos 45^\circ) = 20.0 \text{ kips} \end{aligned}$$

Since force T acts away from its point of application, it is a tensile force (correct answer D).

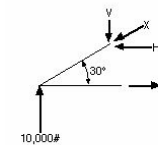


A free body diagram of the end of a truss is shown below. What is the force in the inclined member?



- A. 10,000# compression
- B. 17,321# compression
- C. 20,000# compression
- D. 20,000# tension

The answer is 20,000# COMPRESSION. Let's draw the free body diagram, assuming the force in the inclined member to be compression (pushing on the member). We call the force X, whose vertical and horizontal components are V and H.

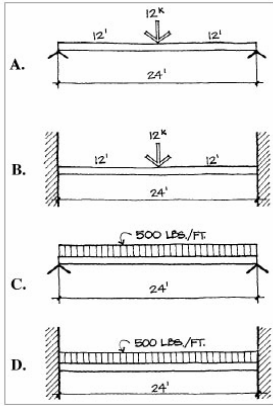


$$\begin{aligned} \sum V &= 0 \\ +10,000 - V &= 0 \\ V &= 10,000\# \\ X &= V / \sin 30^\circ \\ &= 10,000 / 0.500 \\ &= 20,000\# \end{aligned}$$

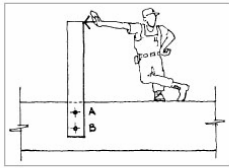
Since the answer comes out positive, our assumption that the member is in compression is correct.

Which of the loadings shown below will produce the greatest deflection?

Many exam questions require no calculations, but instead test your intuitive grasp of structures. In this case, it isn't necessary to calculate the deflection for each loading condition in order to answer the question. It should be obvious that a simple beam (A or C) will deflect more than a fixed-end beam with the same span and load (B or D). Also, a concentrated load at midspan (A) will produce more deflection than the same load uniformly distributed (C).



Which of the following statements about the connection shown is true?

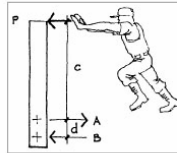


- A. The forces in bolts A and B are equal.
- B. The force in bolt A is greater than that in bolt B.
- C. The force in bolt B is greater than that in bolt A.
- D. The connection is unstable.

We solve this problem by applying two of the basic equations of equilibrium:

$$\Sigma H = 0 \text{ and } \Sigma M = 0.$$

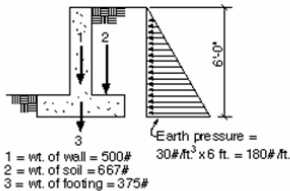
Isolating the vertical member and taking moments about bolt A



$$\begin{aligned} -Pc + Bd &= 0 \\ B &= Pc/d \\ \Sigma H &= 0 \\ A - P - B &= 0 \\ A &= B + P \end{aligned}$$

Therefore, the force in bolt A is greater than that in bolt B (correct answer B).

Assuming a coefficient of friction of 0.5, what is the factor of safety against sliding for the retaining wall shown below? All loads shown are per lineal foot of wall.



- A. 1.08
- B. 1.43
- C. 2.86
- D. 4.28

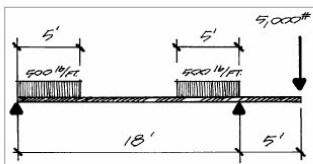
The answer is 1.43. The factor of safety against sliding is equal to the sliding resistance divided by the force tending to cause sliding. The sliding resistance is the total vertical load on the footing multiplied by the coefficient of friction = $(500 + 667 + 375) \times 0.5 = 771\#$. The horizontal load on the wall increases linearly from zero at the top to $180\#$ per foot at the bottom. The total force tending to cause sliding is the average horizontal load of $180 / 2 = 90\#$ per foot multiplied by the height of 6 feet = $540\#$. The factor of safety against sliding is therefore $771 / 540 = 1.43$. Since this is less than the usual requirement of 1.5, additional sliding resistance would have to be provided, possibly by adding an integral key to the footing.

The overturning moment on a retaining wall is 5,000 ft-lbs. per lineal foot. The dead load resisting moment should be at least

- A. 3,333 ft-lbs.
- B. 5,000 ft-lbs.
- C. 7,500 ft-lbs.
- D. 10,000 ft-lbs.

The answer is 7,500 FT-LBS. For a retaining wall, the dead load resisting moment must be at least 1.5 times the overturning moment, or in this case, $1.5 \times 5,000 = 7,500$ ft-lbs.

What is the maximum moment in the beam shown?



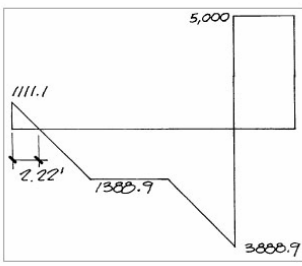
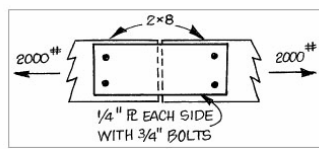
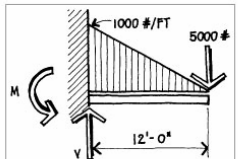
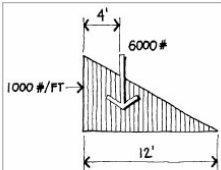
- A. 25,000#
- B. 11,250#
- C. 1,235#
- D. 50,000#

In any beam problem, we must first determine the reactions, then the shears, and finally the moments. To solve for the left reaction, we take moments about the right support.

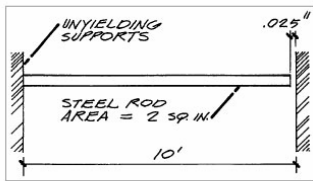
$$\begin{aligned} \Sigma M &= 0 \\ 5000(5) - 500(5)(2.5) - 500(5)(13+2.5) \\ + R_L(18) &= 0 \\ 25,000 - 6,250 - 38,750 + 18R_L &= 0 \\ 18R_L &= 38,750 + 6,250 - 25,000 = 20,000 \\ R_L &= 20,000/18 = 1111.1\# \end{aligned}$$

Now solving for the right reaction,

$$\begin{aligned} \Sigma V &= 0 \\ 1,111.1 + R_R - 500(5) - 500(5) - 50,000 &= 0 \\ R_R &= 2,500 + 2,500 + 50,000 - 1,111.1 \\ R_R &= 8,888.9\# \end{aligned}$$

	<p>Although not absolutely necessary, we will now draw the shear diagram for this beam.</p>  <p>The maximum moment occurs where the shear is equal to zero, which occurs at two places: 2.22 feet from the left support and at the right support. We therefore calculate the moment at each of these two points.</p> <p>Moment at 2.22 from left support = $1,111.1 (2.22) - 500 (2.22)^2/2 = 1,235\#$ Moment at right support = $5,000 (5) = 25,000\#$</p> <p>This is the maximum moment (correct answer A). Incidentally, this moment is negative---that is, it causes tension in the top beam fibers and compression in the bottom fibers.</p>
<p>A column load of 200 kips is supported by a pad footing. Neglecting the weight of the column and footing, what size pad should be used, if the allowable soil bearing value is 4 tons per square foot?</p> <p><input type="radio"/> A. 7'-2" square <input type="radio"/> B. 5'-0" square <input type="radio"/> C. 5'-8" square <input type="radio"/> D. 6'-0" square</p>	<p>We divide the column load by the allowable soil bearing value to obtain the required area of the pad. Remembering that 1 ton equals 2,000 pounds, the required pad area = $200,000/4(2,000) = 25.0$ sq. ft. For a square pad, the required dimension of each side = the square root of 25 = answer B.</p>
<p>A steel bar 1 1/2 inches in diameter and 25 feet long stretches 0.18" when subject to a load. If the modulus of elasticity E is equal to 29,000,000 psi, what is the unit stress in the bar?</p> <p><input type="radio"/> A. 20,880 psi <input type="radio"/> B. 17,400 psi <input type="radio"/> C. 36,000 psi <input type="radio"/> D. 10,191 psi</p>	<p>This question tests your understanding of the relationship among stress, strain, and modulus of elasticity. Up to the elastic limit, the ratio of unit stress (load divided by area, or P/A) to unit strain (deformation divided by length, or Δ/L) is constant and equal to the modulus of elasticity (E). Thus,</p> $(P/A) / (\Delta/L) = E, \text{ or } \Delta = PL/AE.$ <p>In this case,</p> $0.18 = P(25 \times 12) / A(29,000,000)$ <p>$P/A = 0.18(29,000,000)/25 \times 12 = 17,400$ psi (correct answer B). Note that the units must be consistent: P/A is in pounds per square inch (psi), E is in pounds per square inch (psi), Δ is in inches, and L is in inches.</p>
<p>For the connection shown, each 3/4" bolt has an allowable load as follows:</p> <p>Single shear parallel to grain: 710# Single shear perpendicular to grain: 270# Double shear parallel to grain: 1,420# Double shear perpendicular to grain: 540#</p> <p>What is the minimum number of 3/4" bolts required in each 2 x 8?</p>  <p><input type="radio"/> A. 2 <input type="radio"/> B. 3 <input type="radio"/> C. 4 <input type="radio"/> D. 5</p>	<p>To solve this problem, you need to know two things: is the bolt load parallel or perpendicular to the grain, and are the bolts in single or double shear? Since the grain is approximately parallel to the length of each 2 x 8 member, and the 2,000# load is shown applied parallel to each member, the load is parallel to the grain. And since there is a steel plate on each side of the 2 x 8s, it is a double shear connection. Therefore, each bolt has an allowable load of 1,420#. The minimum number of bolts required on each side of the joint, that is, in each 2 x 8, is equal to the load of 2,000# divided by the bolt value of 1,420# = $2,000/1,420 = 1.41$ bolts. We must therefore use at least 2 bolts in each 2 x 8.</p>
<p>The temperature of a steel bar 20 feet long is increased from 70° to 110°F. How much does it expand? (The coefficient of thermal expansion of steel is 0.0000065.)</p> <p><input type="radio"/> A. 0.0143" <input type="radio"/> B. 0.0624" <input type="radio"/> C. 0.0052" <input type="radio"/> D. 0.1716"</p>	<p>All materials expand when heated and contract when cooled. The amount of expansion or contraction is equal to the product of three quantities: the coefficient of thermal expansion, the length of the member, and the temperature change. Therefore, the amount that the bar expands = $(0.0000065) \times (20 \times 12) \times (110 - 70) = 0.0624$". Note that we convert the length of 20 feet to (20×12) inches in order to have the result come out in inches.</p>
<p>A cantilever beam is loaded as shown below. What is the magnitude of the moment M at the fixed end, neglecting the weight of the beam?</p>  <p><input type="radio"/> A. M = 84,000 ft.-lbs. <input type="radio"/> B. M = 96,000 ft.-lbs. <input type="radio"/> C. M = 108,000 ft.-lbs. <input type="radio"/> D. M = 132,000 ft.-lbs.</p>	 <p>First, what is the resultant of the triangular load? It is simply the area of the triangle, which is $(1000\#/ft. / 2) \times 12$ ft. = 6000#, applied at the centroid of the triangle, which is 12 ft. $\div 3 = 4$ ft. from the left end. $\Sigma V = 0 + V - 6000\# - 5000\# = 0$ $V = 11,000\#$ $\Sigma M = 0 (6000\# \times 4$ ft.) + $(5000\# \times 12$ ft.) - $M = 0$ $M = 24,000 + 60,000 = 84,000$ ft.-lbs. Therefore, choice A is correct.</p>

What is the temperature increase necessary to close the gap in the diagram shown?



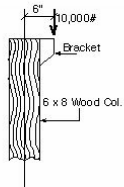
- A. 38.46°F
- B. 32.05°F
- C. 16.03°F
- D. 64.10°F

All materials expand when heated and contract when cooled. The ratio of unit strain to temperature change is called the coefficient of thermal expansion and is constant for a given material. For steel, its value is 0.000065.

Coefficient of thermal expansion
 $\alpha = 0.000065$
 Change of length $\Delta = 0.025$ in
 Length $L = 10$ ft = 120 in
 Temperature change ($^{\circ}$ F) = dT
 $\alpha = (\Delta/L)/dT$ $dT = \Delta/\alpha L$
 $dT = 0.025/(0.000065)(120) = 32.05^{\circ}$ F

(correct answer B). Note that the length and the change of length must be in the same units. In this case, it was necessary to convert the 10 foot length to 120 inches.

A 6 x 8 wood column supports a vertical load of 10,000# applied six inches from its center line, as shown below.



This column is 16 feet long and is oriented so that the bending is about its strong axis. What is the maximum unit stress in the column? The column's properties are: $A = 41.25$ in², $Z = 51.56$ in³, $I = 193.4$ in⁴.

- A. 1406 psi
- B. 1164 psi
- C. 922 psi
- D. 242 psi

This problem involves an eccentrically loaded wood column, that is, a column which supports vertical load applied at some distance from its center line. The vertical load causes a unit stress of $P/A = 10,000\# \div 6$ in. = 60,000 in.-lbs. and causes a flexural stress equal to
 $M/S = 60,000$ in.-lbs. / 51.56 in³ = 1164 psi.

The combined compression and flexural stress = $P/A + M/S = 242 + 0 - 1164$ psi = +1406 psi (compression) or -922 psi (tension). Since the question asked for the maximum unit stress, the answer is 1406 psi. Notice that the length of the column and its moment of inertia I are irrelevant. This is the case with some exam questions; you don't necessarily need all the information given to answer a question.

The maximum moment in a beam of ASTM A36 steel is 500 ft.-kips. What is the required section modulus of the beam?

- A. 139 in³
- B. 167 in³
- C. 250 in³
- D. 500 in³

To solve this problem, we use the basic flexure formula S (required section modulus) = M (moment) divided by F_b (allowable flexural stress) or $S = M/F_b$. The value of F_b for a steel beam is $0.66F_y$, which for ASTM A36 steel is $0.66 \times 36 = 24$ ksi. Thus, $S = 500 \times 12/24 = 250$ in³. Note that we convert the moment of 500 ft.-kips to inch-kips by multiplying by 12, so that the section modulus S comes out in inches³.

A building with a column spacing of 24 feet in each direction supports one floor and a roof. The roof dead load is 20 psf, the roof live load is 20 psf, the floor dead load is 75 psf, and the floor live load is 100 psf. The dead loads include the weights of all framing members and columns. The allowable soil bearing pressure is 4,000 psf. Neglecting any live load reduction, what is the minimum size pad footing which should be used under a typical interior column?

- A. 4'-8" x 4'-8"
- B. 5'-0" x 5'-0"
- C. 5'-8" x 5'-8"
- D. 6'-0" x 6'-0"

In this problem, we first determine the tributary area of each column, that is, the floor area or roof area supported by the column. This extends halfway to the adjacent columns. The tributary area is therefore 24 feet x 24 feet = 576 square feet. The total roof load is 20 psf + 20 psf = 40 psf. The total floor load is 75 psf + 100 psf = 175 psf. The total load is the load in psf (pounds per square foot) multiplied by the tributary area in square feet = $(40 + 175) \times 576 = 123,840\#$. The minimum area of pad required is equal to the load divided by the allowable soil bearing pressure = $123,840/4000 = 30.96$ square feet. The minimum required size of the square pad is the square root of 30.96, or 5.56 feet = 5'-7". We therefore select answer C, 5'-8" x 5'-8".

A glued laminated member 12 inches deep has an allowable unit bending stress of 2400 psi. What is the allowable unit bending stress for a member of the same grade which is 24 inches deep?

- A. 2400 psi
- B. More than 2400 psi
- C. Less than 2400 psi
- D. Not determinable from the information given

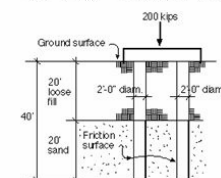
When a glued laminated member is 12 inches or less in depth, the full allowable stress may be used for design. For depths greater than 12 inches, a size factor is used, which has the effect of reducing the allowable stress that may be used. C is therefore the correct answer.

The soils report for a project recommends the use of friction piles to extend through 20 feet of loose fill to reach a lower layer of dense sand. If two 24-inch-diameter concrete piles are used to support a column with a load of 200 kips, what should be the length of each pile below the ground surface? The sand has an allowable load friction of 800 psf.

- A. 20 feet
- B. 30 feet
- C. 40 feet
- D. 60 feet

The answer is 40 FEET. Friction piles are often used where soils at the ground surface are not adequate to support a building's loads. Friction piles obtain their load-carrying capacity by the friction between the vertical surface area of the pile and the surrounding soil.

Pile diameter = $D = 2$ feet
 Pile surface area per foot of length =
 pile circumference = $pD = p \times 2$ feet = 6.28 ft²/ft.
 Pile capacity per foot of length = friction \times area =
 $800 \#/\text{ft}^2 \times 6.28 \text{ ft}^2/\text{ft} = 5024 \#/\text{ft} = 5.02$ kips/ft.
 Required length of 2 piles into sand =
 load / capacity for 2 piles = 200 kips / 2 piles $\times 5.02 = 19.9$ ft.
 Required length of 2 piles below ground surface =
 depth to top of sand + embedment into sand =
 20 ft + 19.9 ft = 29.9 ft, say 40 feet (answer C).



Show two methods for building up a wood beam by nailing individual laminations together. Which of the following are the advantages of beam 1 over beam 2?

I. Less deflection
 II. Lower flexural stress
 III. Lower horizontal shear stress
 IV. Higher allowable flexural stress

○ A. I, II, III, IV
 ○ B. I, II, III
 ○ C. I, II
 ○ D. III only

This question tests your understanding of basic beam theory. Beam 1 consists of 4 beams 1 1/2" wide by 12" deep. The section modulus of each is $bd^2/6 = 1.5(12)^2/6 = 36 \text{ in}^3$, and the total section modulus is equal to $4 \times 36 = 144 \text{ in}^3$. The moment of inertia of each lamination is $bd^3/12 = 1.5(12)^3/12 = 216 \text{ in}^4$, and the total moment of inertia is $216 \times 4 = 864 \text{ in}^4$. Beam 2 consists of 8 beams 6" wide by 1 1/2" deep. The section modulus of each is $bd^2/6 = 6(1.5)^2/6 = 2.25 \text{ in}^3$, and the total section modulus is $8 \times 2.25 = 18 \text{ in}^3$. The moment of inertia of each lamination is $bd^3/12 = 6(1.5)^3/12 = 1.6875 \text{ in}^4$, and the total moment of inertia is equal to $8 \times 1.6875 = 13.5 \text{ in}^4$. Summarizing, S for beam 1 is 144 and S for beam 2 is 18. I for beam 1 is 864 and I for beam 2 is 13.5. Since the bending resistance of a beam is a function of its section modulus, beam 1 is 8 times as strong in bending as beam 2 ($144/18 = 8$). Put another way, for the same span and load, the flexural stress of beam 1 will be only 1/8 that of beam 2. The deflection resistance, or stiffness, of a beam is a function of its moment of inertia. Therefore, beam 1 is 64 times as stiff as beam 2 ($864/13.5 = 64$). Or, in other words, for the same span and load, beam 1 will only deflect 1/64 as much as beam 2. Choices I and II are therefore correct. The horizontal shear stress for a rectangular beam is equal to $3/2 V/bd$. For beam 1, bd is equal to $4 \times 1.5 \times 12 = 72$ square inches. For beam 2, bd is $8 \times 6 \times 1.5 = 72$ square inches. Therefore, the horizontal shear stresses in beams 1 and 2 are equal, making choice III incorrect. Choice IV is also incorrect, because there is nothing in the problem statement which relates to allowable stress. C is therefore the correct answer. It is not necessary to actually perform any calculations in this question—we have done so in order to show that narrow deep beams have much greater bending resistance and resistance to deflection than wide shallow beams.

Also, that horizontal shear stress in a rectangular beam is a function only of its area. Also, note that the individual laminations are nailed together. If they were bonded by glue, or otherwise connected so as to develop adequate shear strength, they could be made to act as one beam instead of separate laminations.

In designing the floor framing of a building, the deflection of a steel beam under load is calculated to be 1.50 inches. The properties of the beam are:

- Area $A = 19.7 \text{ in}^2$
- Section modulus $S = 117 \text{ in}^3$
- Moment of inertia $I = 954 \text{ in}^4$
- Yield stress $F_y = 36 \text{ ksi}$
- Modulus of elasticity $E = 29 \times 10^6 \text{ psi}$

We wish to limit the deflection to 1.0 inch. How can we best accomplish this?

○ A. Change the yield stress to 50 ksi
 ○ B. Change the modulus of elasticity to at least $43.5 \times 10^6 \text{ psi}$
 ○ C. Use a different beam with a section modulus of at least 175.5 in^3
 ○ D. Use a different beam with a moment of inertia of at least 1431 in^4

The answer is D. This question asks how the deflection of a beam can be reduced. All deflection formulas are in the form

$$\Delta (\text{maximum deflection}) = L^2/EI$$

multiplied by a factor which depends on the size and nature of the loading. In this formula, L is the span, E is the modulus of elasticity, and I is the moment of inertia. Since we can't change the loading or the span, and E for steel has a constant value, the only variable is I, the moment of inertia. So, to reduce the deflection from 1.50 inches to 1.0 inch, we must increase the moment of inertia in the ratio 1.5/1.0. The original I is

$$954 \text{ in}^4,$$

so we must substitute a beam with an I value of at least 1.5 times 954, or

$$1431 \text{ in}^4$$

(correct answer D). Notice that most of the data given in this question (area, section modulus, yield stress, and modulus of elasticity) is irrelevant. This is often the case on the exam, so be prepared for it.

A sawn wood beam of Douglas Fir-Larch No. 1 grade with the following loading diagram has a maximum shear of 4,000# and a maximum moment of 16,000 ft-#.

If the allowable shear stress is 85 psi and the allowable bending stress is 1300 psi, what is the minimum required area and section modulus for the beam?

○ A. $A = 70.6 \text{ in}^2$, $S = 147.7 \text{ in}^3$
 ○ B. $A = 47.1 \text{ in}^2$, $S = 147.7 \text{ in}^3$
 ○ C. $A = 70.6 \text{ in}^2$, $S = 12.3 \text{ in}^3$
 ○ D. $A = 47.1 \text{ in}^2$, $S = 12.3 \text{ in}^3$

The formula for the required area of a wood beam for shear stress is

$$A = 3V/2F_v$$

Substituting the given values of 4,000# for V, and 85 psi for F_v we have

$$\text{Area} = A = (3 \times 4,000)/(2 \times 85) = 70.6 \text{ in}^2.$$

The formula for the required section modulus of a wood beam for bending stress is: $S = M/F_b$. Substituting the given values of 16,000 ft-# for M, and 1,300 psi for F_b , and remembering to convert all units to # and inches, we have:

$$\text{Section Modulus} = S = (16,000 \text{ ft-#} \times 12 \text{ in/ft})/13,000 = 147.7 \text{ in}^3$$

Thus the correct answer is A. If you selected answer C or D, you probably forgot to convert the moment in ft-# to in-# by multiplying the moment by 12 to keep the units consistent. If you selected answer B or D, you likely forgot to multiply V/F_v by 3/2. Once the required area A and section modulus S have been determined, the member may be selected from a table of properties.

Which of the retaining wall sections below show the correct placement of reinforcing steel?

○ A. I and II
 ○ B. II and III
 ○ C. III and IV
 ○ D. I, II, and III

Reinforcing steel must be placed in the tension face of a reinforced concrete structure, that is, the face which elongates or stretches under load. Thus, by visualizing the shape of the deflected structure, one can determine where the reinforcing steel should be placed. In the diagrams below, the retaining walls are acted on by the loads shown, causing them to deflect as indicated by the dashed lines.

In I and III, the face of the wall closest to the earth and the upper face of the footing are in tension. Therefore, I has the reinforcing steel correctly placed, while III does not, since the steel is shown closest to the bottom face of the footing. In II and IV, the face of the wall closest to the earth and the bottom face of the footing are in tension. It shows the correct placement of the reinforcing steel, while IV does not, since the steel is shown in the face of the wall furthest from the earth. Since I and II show the correct placement of reinforcing steel, A is the correct answer.