ASCE NATIONAL CAPITAL SECTION
eNewsletter
National Capital Section
FOUNDED 1916

SEPTEMBER 2016

DR. Z's CORNER

Conquering the FE & PE exams
Problems & Applications

This Month's Topics

- FE CIVIL Exam & Topics - Number of Questions
- Types of Calculators / Both in FE and PE Exams
- Technology Usage, CASIO fx 115-Plus
- Mathematics, Conic Sections
- Probability & Statistics
- Engineering Economy
- Geotechnical Engineering
- Statics & Centroids & Moments of Inertia
- Strength of Material / Deflections & Trusses
- Structures / Shear & Moment Diagrams
- Strength of Materials / Determinate Frames
- Strength of Materials / Determinate Structures
- Photo / Dr. Z's Pro Bono Saturday Classes

CALCULATORS

FOR USE IN FE / PE EXAMS

To protect the integrity of FE/PE exams, NCEES limits the types of calculators you may bring to exam sites. The only calculator models acceptable for use during the 2016 exams are as follows:

Casio: All fx-115 models. Any Casio calculator must contain fx-115 in its model name.

- fx-115 MS
- **Fx-115 ES PLUS** (We recommend this model)
- fx-115 ES

Texas Instruments: All TI-30X and TI-36X models. Any Texas Instruments calculator must contain either TI-30X or TI-36X in its model name. Examples of acceptable TI-30X and TI-36X models include (but are not limited to):

- TI-30Xa
- TI-30Xa SOLAR
- TI-30Xa SE
- TI-30XS Multiview
- TI-30X IIB
- TI-30X IIS
- TI-36X II
- TI-36X SOLAR
- TI-36X Pro

Hewlett Packard:

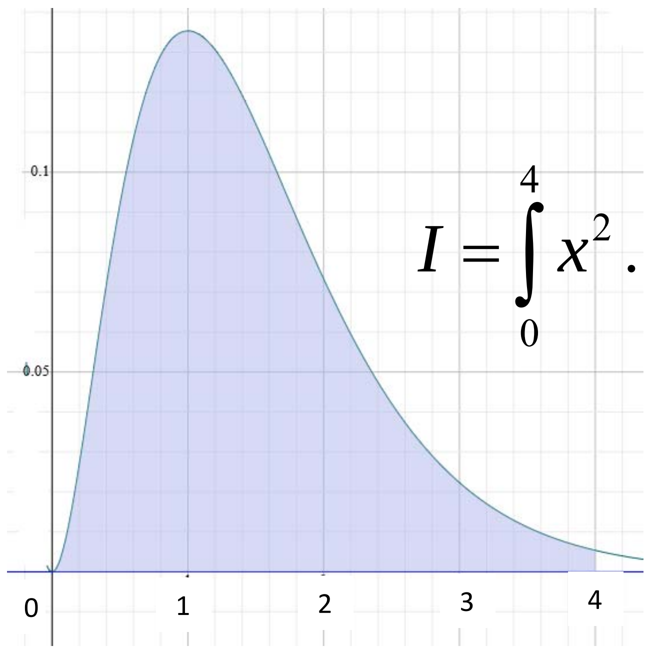
Only HP 33s and HP 35s models, no others.

DEFINITE INTEGRALS

TECHNOLOGY USAGE

CASIO FX-115 ES PLUS

Problem:



$$I = \int_0^4 x^2 \,.\, e^{-2x} \, dx$$

The area under the graph shown is most nearly:

(A) 355.5
(B) 14. 5
(C) 2.15
(D) 0.25

TECHNOLOGY USAGE

$$I = \int_{0}^{4} x^2 . e^{-2x} \, dx$$

ANSWER

CASIO-245
ZEYTINCI
SEPT 2016

FUNDAMENTALS OF ENGINEERING

DOMAIN: MATHEMATICS

CONIC SECTIONS

NCEES-Reference Handbook 9.4 / Page-26

1- Parabola (eccentricity = 1)

$$(y - k)^2 = 2p(x - h)$$

Center: (h, k)

2- Ellipse (eccentricity < 1)

$$\frac{(x-h)^2}{a^2} + \frac{(y-k)^2}{b^2} = 1$$

Center: (h, k)

3- Hyperbola (eccentricity > 1)

$$\frac{(x-h)^2}{a^2} - \frac{(y-k)^2}{b^2} = 1$$

Center: (h, k)

4- Circle (eccentricity = 0)

$$(x - h)^2 + (y - k)^2 = r^2$$

Center: (h, k)

Radius:

$$r = \sqrt{(x-h)^2 + (y-k)^2}$$

FUNDAMENTALS OF ENGINEERING

DOMAIN: MATHEMATICS

ELLIPSE

$$\frac{(x - h)^2}{a^2} + \frac{(x - k)^2}{b^2} = 1$$

Center: (h, k)

In simple terms, in a cartesian coordinate plane, an ellipse is in standard position when its principal axis conincides with one of the coordinate axes (*x* and *y axes*) and its center coincides with the origin (*O*).

Problem: (Conic Sections)

$$16\,x^2 + 25\,y^2 = 400$$

The equation of a conic section given above most nearly represents:

(A) a circle
(B) a parabola
(C) a hyperbola
(D) an ellipse

Problem: (Conic Sections / Ellipse)

The equation of the ellipse with center at (0, 2), vertex (0, 6) and semiminor axis of length *b* = 3 is most nearly:

(A) $16\,x^2 + 9\,(y + 2)^2 = 169$
(B) $36\,x^2 + 7\,(y - 2)^2 = 169$
(C) $25\,x^2 - 9\,(y + 2)^2 = 144$
(D) $16\,x^2 + 9\,(y - 2)^2 = 144$

FUNDAMENTALS OF ENGINEERING

DOMAIN: MATHEMATICS

Problem: (Conic Sections)

$$4x^2 + 9y^2 - 8x + 36y + 4 = 0$$

The equation of a conic section given above most nearly represents:

(A) circle
(B) parabola
(C) hyperbola
(D) ellipse

Problem: (Conic Sections)

$$4x^2 + y^2 + 16x - 2y + 13 = 0$$

The equation of a conic section given above most nearly represents:

(A) circle
(B) parabola
(C) hyperbola
(D) ellipse

Problem: (Conic Sections)

$$9x^2 + 25y^2 - 6x + 10y - 223 = 0$$

The equation of a conic section given above most nearly represents:

(A) circle
(B) parabola
(C) hyperbola
(D) ellipse

FUNDAMENTALS OF ENGINEERING

DOMAIN: MATHEMATICS

CONIC SECTIONS

Problem: (Conic Sections / Ellipse)

The equation of the ellipse with center at C (2, 1), focus (0, 1) *semimajor* axis of length *a* = 3 is most nearly:

(A) $x^2 + 9(y + 2)^2 - 225 = 0$

(B) $5x^2 + 9y^2 - 20x - 18y = 144$

(C) $5x^2 - 9y^2 - 20x - 18y = 16$

(D) $5x^2 + 9(y - 1)^2 = 144$

Problem: (Conic Sections / Ellipse)

The equation of the ellipse with center at C (0, 0), focus F (-2, 0) and major axis of length = 8 is most nearly:

(A) $14x^2 - 16y^2 = 192$

(B) $12x^2 + 16y^2 = 192$

(C) $12x^2 + 16y^2 = 136$

(D) $16x^2 + 25y^2 = 144$

Problem: (Conic Sections / Ellipse)

The equation of the ellipse with center at *C* (0, 0), focus *F* (2, 0) a vertex (3, 0) is most nearly:

(A) $x^2 - 16y^2 = 36$

(B) $5x^2 - 9y^2 = 45$

(C) $5x^2 + 9y^2 - 45 = 0$

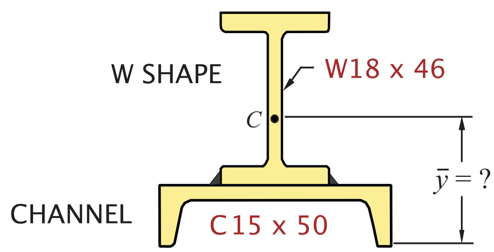
(D) $9x^2 + 5y^2 - 45 = 0$

DESIGN OF STEEL STRUCTURES

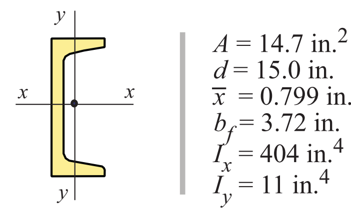
BUILT-UP-SECTIONS

FE/PE EXAM

Problem:



Properties of C 15 x 50



A W-shape section and a channel are welded together to form a built-up-section as shown in the figure. Using the listed data answer the following questions:

(1) the distance y_{bar} (in.) for the centroid is most nearly

(A) 9.0
(B) 8.5
(C) 7.6
(D) 6.9

$\bar{y} = ?$

(2) the moment of inertia (in^4) about the horizontal centroidal axis is most nearly

(A) 1250
(B) 1300
(C) 1350
(D) 1400

$I_{cx} = ?$

(3) the moment of inertia (in^4) about the vertical centroidal axis is most nearly

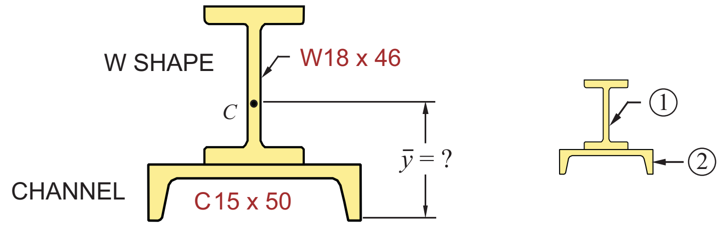
(A) 385
(B) 426
(C) 524
(D) 560

$I_{cy} = ?$

COMPLETE SOLUTION

STEEL 255
ZEYTINCI
SEPT 2016

Centroid / Moments of Inertia



Centroid Computations:

	A_i (in.^{2})	y_i (in.)	$A_i\, y_i$ (in.^{3})
1	13.5	12.770	172.395
2	14.7	2.921	42.939
Σ	**28.2**	—	**215.334**

$$\bar{y} = \frac{\Sigma A_i\, y_i}{\Sigma A_i} = \frac{215.334}{28.2} = 7.64 \text{ in.}$$

Moments of Inertia Computations:

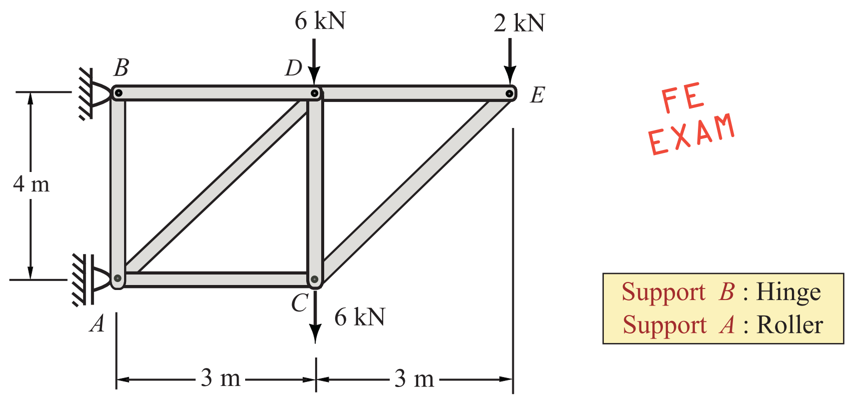
	I_o (in.^{4})	A_i (in.^{2})	d_i (in.)	$A_i\, d_i^2$ (in.^{4})
1	712.0	13.5	5.134	355.84
2	11.00	14.7	4.715	326.79
Σ	**723.0**		—	**682.63**

$$I_x = \Sigma I_o + \Sigma A_i \,.\, d_i^2 = 723.0 + 682.63 = 1405.63 \text{ in.}^4$$

$$I_y = I_{y1} + I_{x2} = 22.5 + 404.0 = 426.50 \text{ in.}^4$$

$$r_{min} = \text{Root}\,(I_{min} / \Sigma A) = \text{Root}\,(426.50 / 28.2) = 3.89 \text{ in.}$$

Problem: (Plane Truss)



The plane truss is subjected to the loads as shown in the figure. Assuming the support *A* is a roller, answer the following questions:

(1) the magnitude of the member force (kN) in BD is most nearly

(A) 12.0
(B) 14.5
(C) 16.0
(D) 18.5

(2) the magnitude of the member force (kN) in AD is most nearly

(A) 25.0
(B) 21.5
(C) 19.0
(D) 17.5

(3) the magnitude of the member force (kN) in AC is most nearly

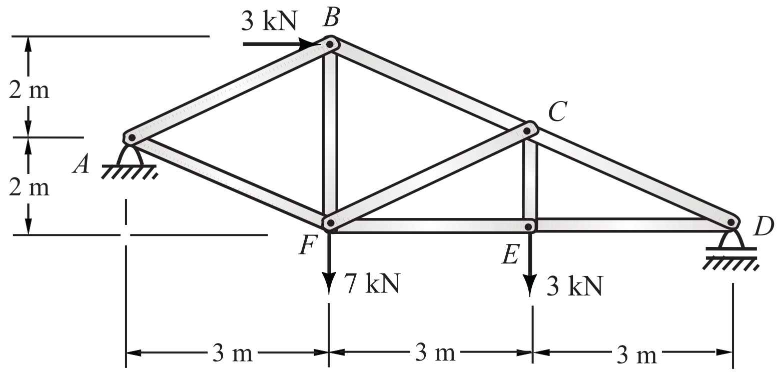
(A) 3.5
(B) 2.0
(C) 1.5
(D) 0.5

(4) the magnitude of the member force (kN) in CD is most nearly

(A) 10.5
(B) 8.0
(C) 6.0
(D) 4.5

Problem: (Plane Truss)

FE/PE EXAM



Support A : Pin
Support D : Roller

The plane truss is subjected to the loads as shown in the figure. Assuming the support A is a pin and D is a roller, answer the following questions:

(1) the magnitude of the member force (kN) in AB is most nearly

- (A) 5.60
- (B) 4.52
- (C) 2.70
- (D) 1.56

(2) the magnitude of the member force (kN) in BC is most nearly

- (A) 7.56
- (B) 6.31
- (C) 5.54
- (D) 4.56

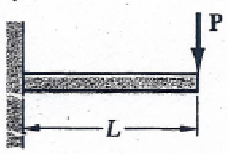
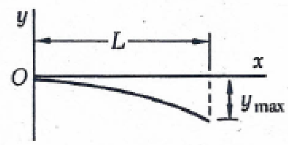
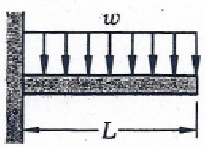
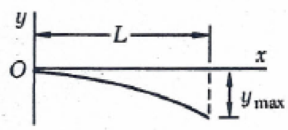
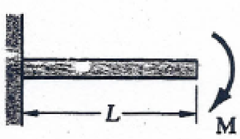
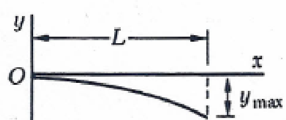
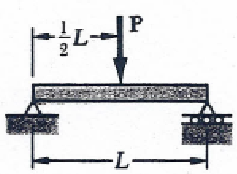
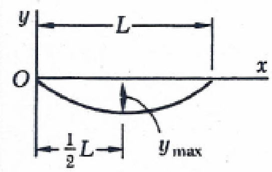
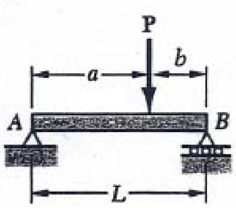
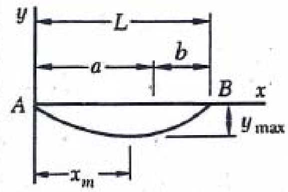
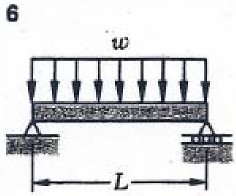
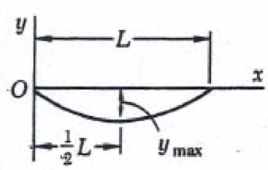
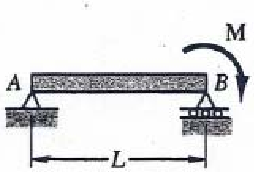
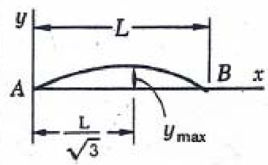
(3) the magnitude of the member force (kN) in FC is most nearly

- (A) 3.58
- (B) 2.70
- (C) 1.54
- (D) 0.58

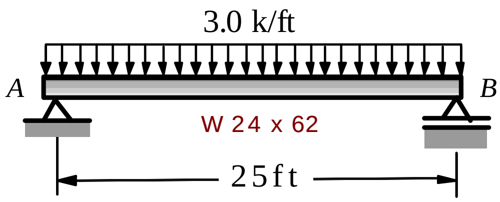
(4) the magnitude of the member force (kN) in FE is most nearly

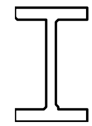
- (A) 10.55
- (B) 9.00
- (C) 7.50
- (D) 5.50

BEAM DEFLECTION FORMULAS

Beam and Loading	Elastic Curve	Maximum Deflection	Slope at End
1 		$\frac{PL^3}{3EI}$	$\frac{PL^2}{2EI}$
2 		$\frac{wL^4}{8EI}$	$\frac{wL^3}{6EI}$
3 		$\frac{ML^2}{2EI}$	$\frac{ML}{EI}$
4 		$\frac{PL^3}{48EI}$	$\frac{PL^2}{16EI}$
5 		For $a > b$ $-\frac{Pb(L^2-b^2)^{3/2}}{9\sqrt{3}EIL}$ at $x_m = \sqrt{\frac{L^2-b^2}{3}}$	$\theta_A = -\frac{Pb(L^2-b^2)}{6EIL}$ $\theta_B = +\frac{Pa(L^2-a^2)}{6EIL}$
6 		$\frac{5wL^4}{384EI}$	$\frac{wL^3}{24EI}$
7 		$\frac{ML^2}{9\sqrt{3}EI}$	$\theta_A = +\frac{ML}{6EI}$ $\theta_B = -\frac{ML}{3EI}$

Problem: (Beam Deflections)



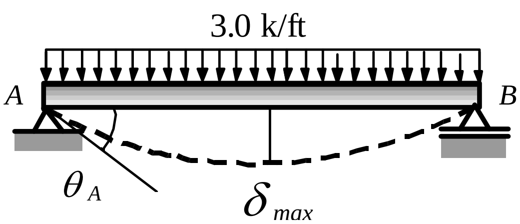


W 24 x 62

E = 29,000 ksi

(a) Determine the maximum deflection
(b) Determine the slope at support *A*

Solution:



Maximum Deflection:
Maximum deflection will be at the midpoint of the span. Using the Correction Factor of (12^3) for deflections:

$$\delta_{\max} = \frac{5}{384}\frac{wL^4}{EI}$$

$$= \frac{5}{384}\frac{(3.0)\,(25)^4}{(29{,}000)(1560)}\,(12^3) = \underline{0.5828 \text{ in.}}$$

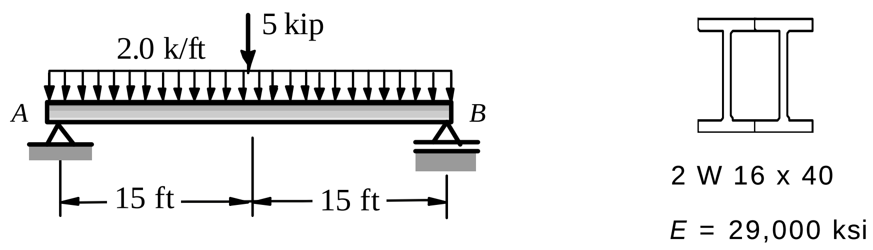
$$\delta_{\max} = 0.5828 \text{ in.}$$

Slope (angle) at point *A*:
For slope calculations use Correction Factor (12^2).

$$\theta_A = \frac{wL^3}{24EI}$$

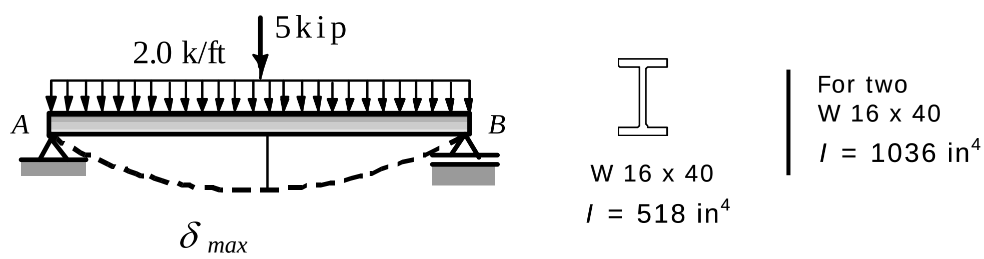
$$= \frac{1}{24}\frac{(3.0)\,(25)^3}{(29{,}000)(1560)}\,(12^2) = 0.00622 \text{ radians } = 0.36^\circ$$

Problem: (Beam Deflections)



Determine the maximum deflection

Solution:



Maximum deflection:

Here two W 16 x 40 sections are welded together so double the *I* value. The maximum deflection will be at the midpoint of the span. Using the **Unit Conversion Factor** of (12^3) for deflections would be convenient.

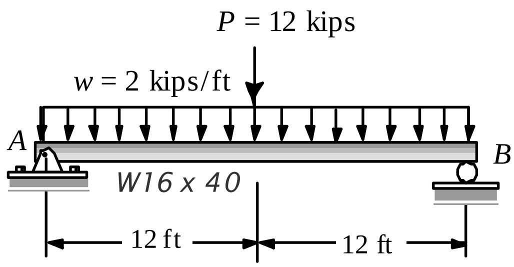
$$\delta_{max} = \frac{5}{384}\frac{wL^4}{EI} + \frac{1}{48}\frac{PL^3}{EI}$$

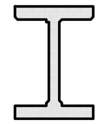
$$= \frac{5}{384}\frac{(2.0)\,(30)^4}{(29{,}000)(1036)}\,(12^3) + \frac{1}{48}\frac{(5)\,(30)^3}{(29{,}000)(1036)}\,(12^3)$$

$$= 1.213 + 0.1618$$

$$= \underline{1.375 \text{ inches}}$$

Problem: (Beam Deflections)



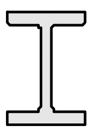


W 16 x 40

E = 29,000 ksi

For the simple beam shown the beam weight is included in the uniform load. Determine the maximum deflection and the slope at A (in radians).

Solution: We will use NCEES-Reference Handbook, page 155 and 81.



W 16 x 40

$I = 518 \text{ in}^4$

FOR DEFLECTIONS : (12^3)

FOR SLOPES : (12^2)

Finding the maximum deflection:

The maximum deflection will be at the midpoint of the span. For quick calculations when using US unit systems, architects and engineers use conversion factors like (12^3) and (12^2). For DEFLECTIONS this conversion factor is (12^3) and for SLOPES the conversion factor will be (12^2).

$$\delta_{max} = \frac{5}{384}\frac{wL^4}{EI} + \frac{1}{48}\frac{PL^3}{EI} = \frac{5}{384}\frac{(2.0)\ (24)^4}{(29{,}000)(518)}(12^3) + \frac{1}{48}\frac{(12)\ (24)^3}{(29{,}000)(518)}(12^3)$$

$= 0.994 + 0.397 =$ **1.391 inches**

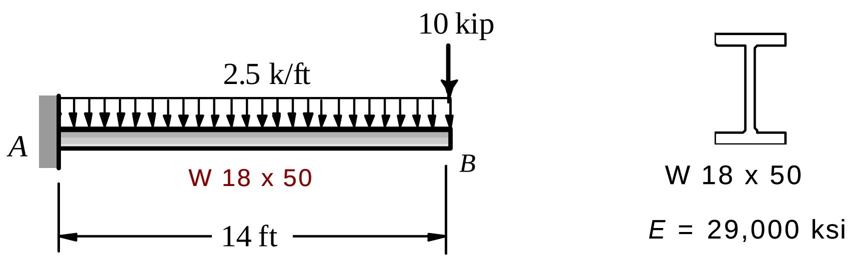
Finding the slope at support A:

$$\theta_A = \frac{wL^3}{24EI} + \frac{PL^2}{16\,EI} = \frac{1}{24}\frac{(2.0)\ (24)^3}{(29{,}000)(518)}(12^2) + \frac{1}{16}\frac{(12)\ (24)^2}{(29{,}000)(518)}(12^2)$$

$= 0.01104 + 0.00414 = 0.01518$ Radians

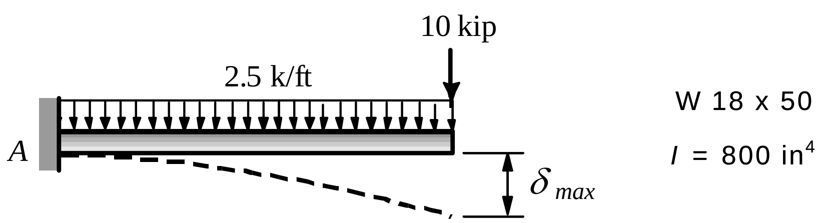
$=$ **0.01518 Radians**

Problem: (Beam Deflection)



Determine the maximum deflection.

Solution:



Maximum deflection:

This is a cantilever beam with a fixed support at A. The maximum deflection will be at the free end as shown. Using the **Unit Conversion Factor** of (12^3).

$$\delta_{\max} = \frac{1}{8}\frac{wL^4}{EI} + \frac{1}{3}\frac{PL^3}{EI}$$

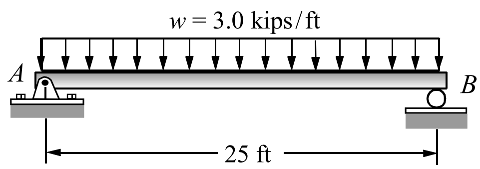
$$= \frac{1}{8}\frac{(2.5)\,(14)^4}{(29{,}000)\,(800)}\,(12^3) + \frac{1}{3}\frac{(10)\,(14)^3}{(29{,}000)\,(800)}\,(12^3)$$

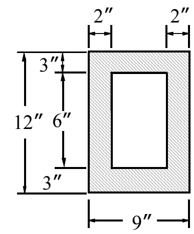
$$= 0.8942 + 0.6813$$

$$= \underline{1.575 \text{ inches}}$$

Problem: (Deflections)

FE EXAM





section

$E = 29 \times 10^6$ psi

$I = 1206\ in^4$

A simple beam is loaded as shown. The beam weight is included in the uniform load. Using the given cross-section and the modulus of elasticity answer the following questions:

(1) the max. deflection (in.) of the beam is most nearly (δ_{max})

(A) 0.456
----> (B) 0.754
(C) 1.120
(D) 1.575

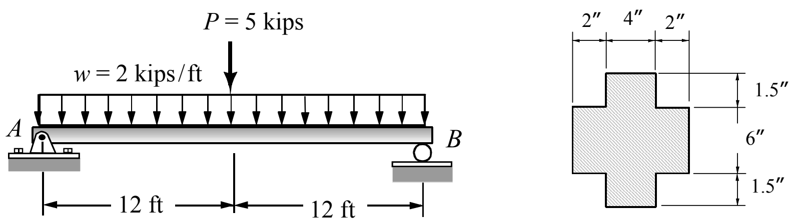
(2) the slope (radians) at support A is most nearly (θ_A)

(A) 0.02655
(B) 0.03584
----> (C) 0.00804
(D) 0.00552

(3) the maximum moment (k.ft) in the beam is most nearly (M_{max})

(A) 114
----> (B) 234
(C) 297
(D) 345

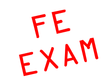
Problem: (Deflections)



section

$E = 29 \times 10^6$ psi

$I = 315\ in^4$



A simple beam is loaded as shown. The beam weight is included in the uniform load. Using the given cross-section and the modulus of elasticity answer the following questions:

(1) the max. deflection (in.) of the beam is most nearly (δ_{max})

(A) 0.75
(B) 1.00
---> (C) 1.91
(D) 2.50

(2) the slope (radians) at support A is most nearly (θ_A)

(A) 1.226
(B) 0.425
(C) 0.055
---> (D) 0.021

(3) the maximum moment (k.ft) in the beam is most nearly (M_{max})

---> (A) 174
(B) 250
(C) 285
(D) 316

DEF-89
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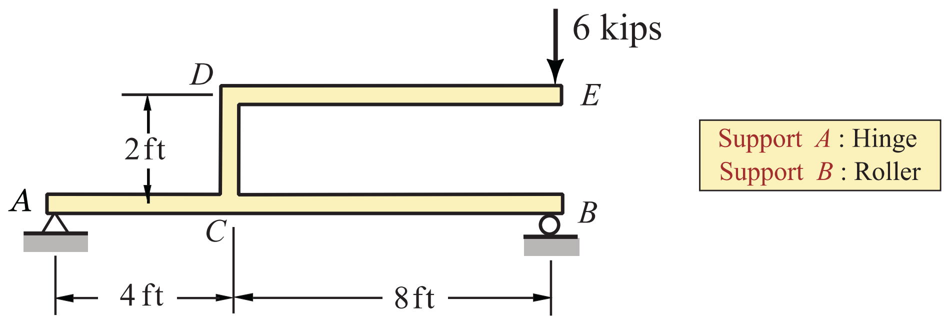
FUNDAMENTALS OF ENGINEERING

MECHANICS OF SOLIDS

Shear Force & Bending Moment Diagrams

Problem: (Strength of Materials)



The rigid bar *CDE* is welded at point *C* to the steel beam *AB* as shown in the figure. The support at *A* is a pin (hinge) and the support at *B* is a roller.

Assuming that the concentrated load P=6k is applied at *E* as shown, answer the following questions:

(1) The ***shear force*** diagram (*V*) of this determinate frame is composed of:

- (A) Two triangles
- (B) Two rectangles
- (C) Three rectangles
- (D) Two traingles and one rectangle

(2) The ***bending moment*** diagram (*M*) of this determinate frame is composed of:

- (A) Three triangles
- (B) Three rectangles
- (C) One triangle and two rectangles
- (D) Two triangles and one rectangle

ANSWERS

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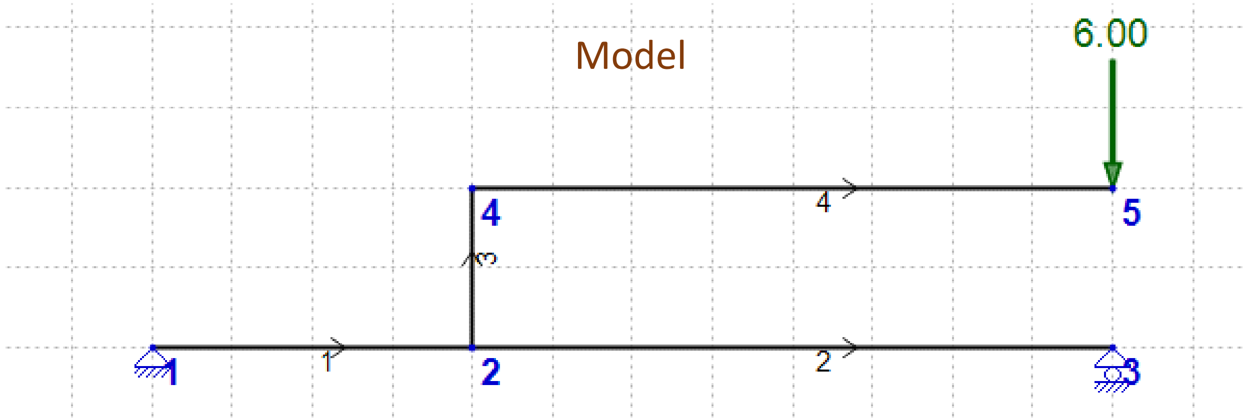
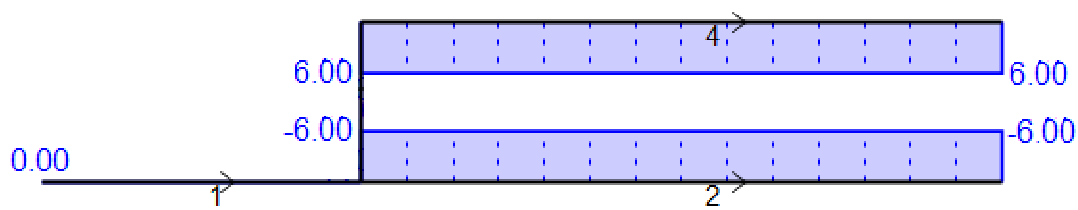
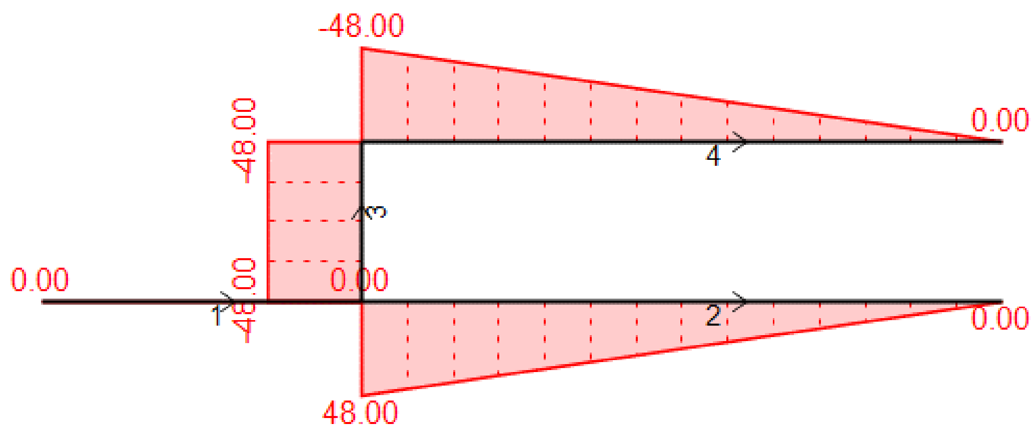
Solution by Dr. Vagelis Plevris



Shear Force Diagram



Bending Moment Diagram



Answers:

(1) B (Two rectangles)

(2) D (Two triangles and one rectangle)

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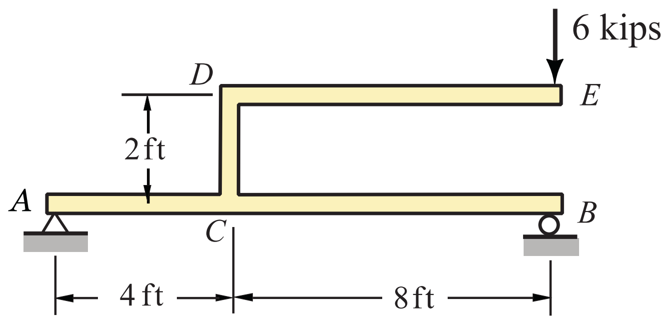
FUNDAMENTALS OF ENGINEERING

MECHANICS OF SOLIDS

Shear Force & Bending Moment Diagrams

Problem: (Strength of Materials)



Support *A* : Hinge
Support *B* : Roller

The rigid bar CDE is welded at point C to the steel beam AB as shown in the figure. The support at A is a pin (hinge) and the support at B is a roller.

Assuming that the concentrated load P=6k is applied at *E* as shown, answer thr following questions:

(1) the support reaction (kips) at *A* is most nearly

(A) 10
(B) 8
(C) 6
(D) 0

(2) the support reaction (kips) at *B* is most nearly

(A) 0
(B) 4
(C) 6
(D) 8

(3) the shear force in member *CD* is most nearly

(A) 10
(B) 9
(C) 7
(D) 0

ANSWERS

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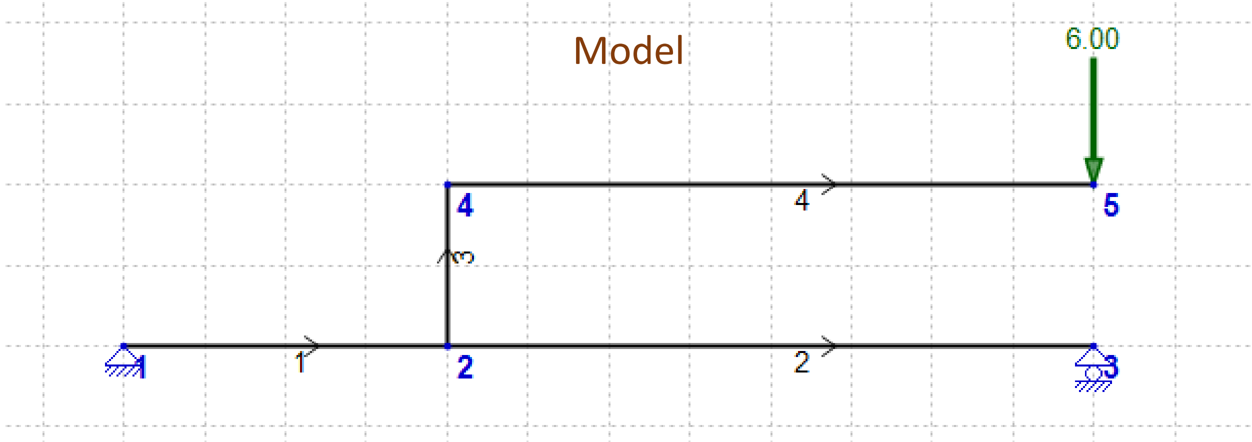
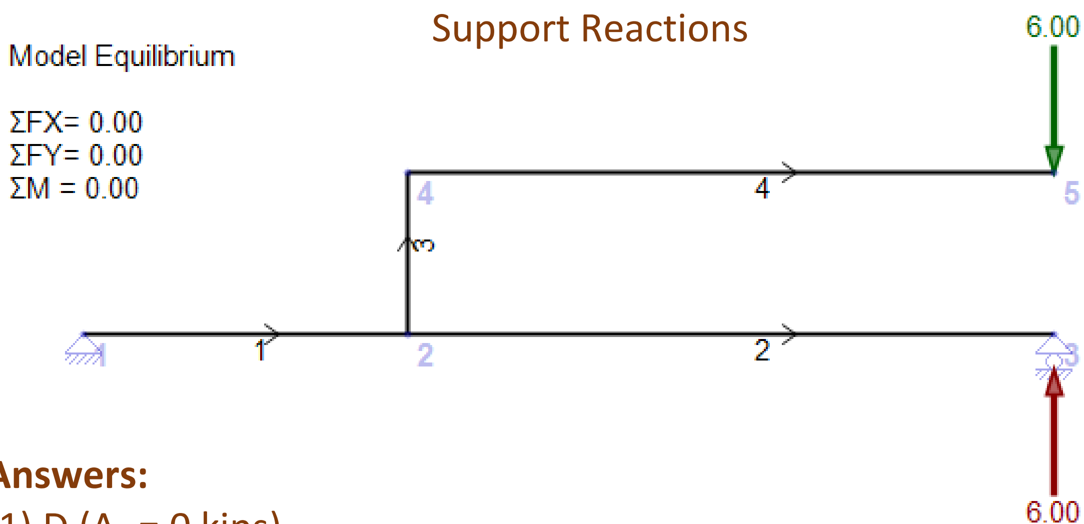
Solution by Dr. Vagelis Plevris

Model



Support Reactions



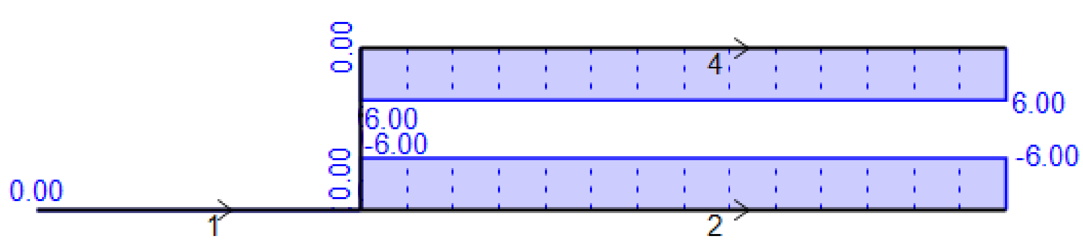
Answers:

(1) D (A_y = 0 kips)

(2) C (B_y = 6 kips)

(3) D (V_{CD} = 0 kips)

Shear Force Diagram



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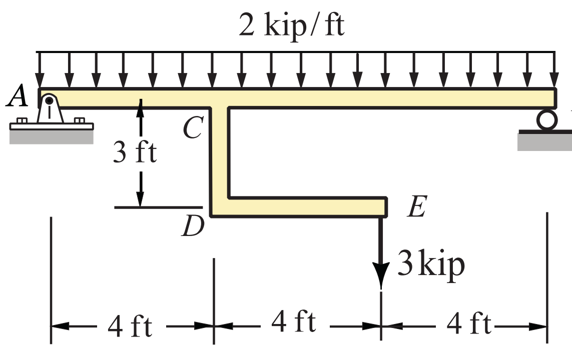
FUNDAMENTALS OF ENGINEERING

MECHANICS OF SOLIDS

Analysis of Determinate Frames

Problem: (Strength of Materials)



Support A : Hinge
Support B : Roller

The rigid bar CDE is welded at point C to the steel beam AB as shown in the figure. The support at A is a pin (hinge) and the support at B is a roller.

Assuming that the 3 kips concentrated load is applied at *E as* shown in the figure, answer the following questions:

(1) the support reaction (kips) at *A* is most nearly

(A) 10
(B) 11
(C) 13
(D) 15

(2) the support reaction (kips) at *B* is most nearly

(A) 12
(B) 14
(C) 15
(D) 16

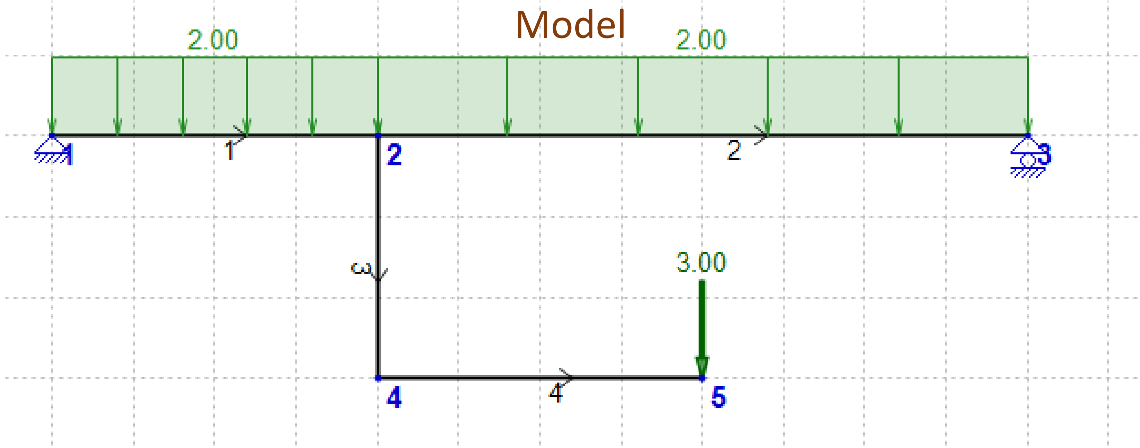
(3) the bending moment (ft-kips) at the middle of AB is most nearly

(A) 48
(B) 40
(C) 55
(D) 34

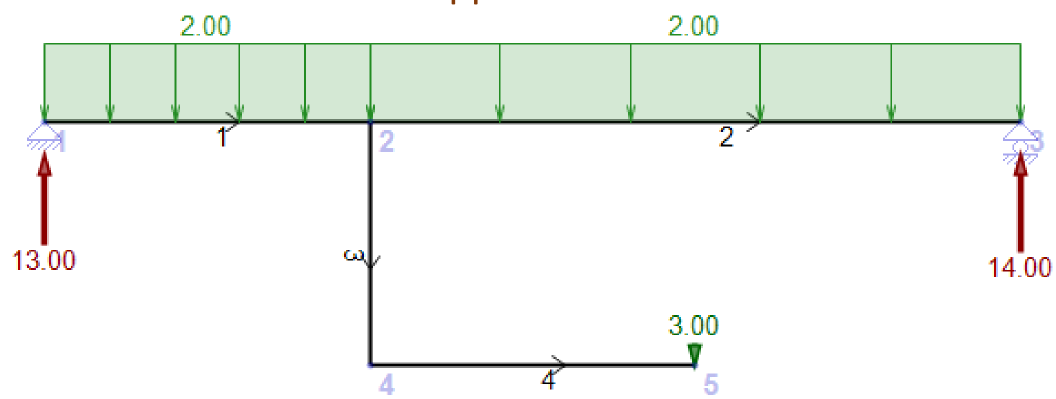
ANSWERS

Solution by Dr. Vagelis Plevris

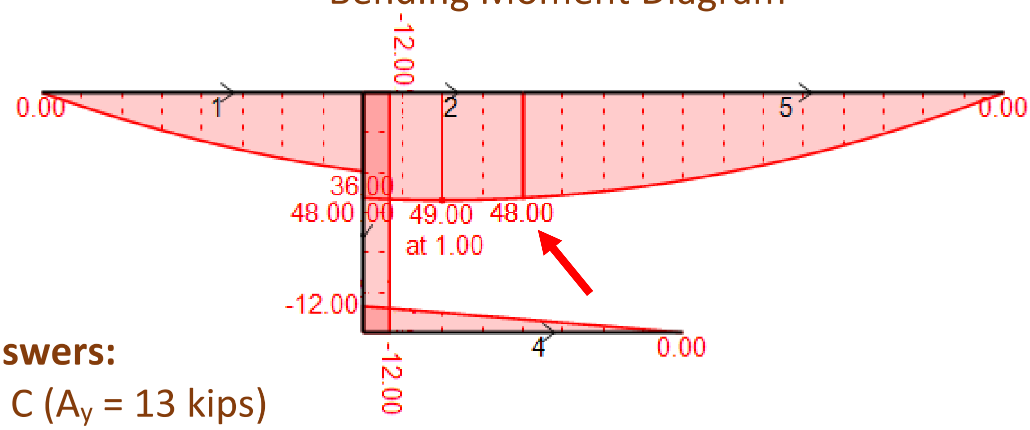
Model



Support Reactions



Bending Moment Diagram



Answers:

(1) C (A_y = 13 kips)

(2) B (B_y = 14 kips)

(3) A ($M_{middle,AB}$ = 48 kips)

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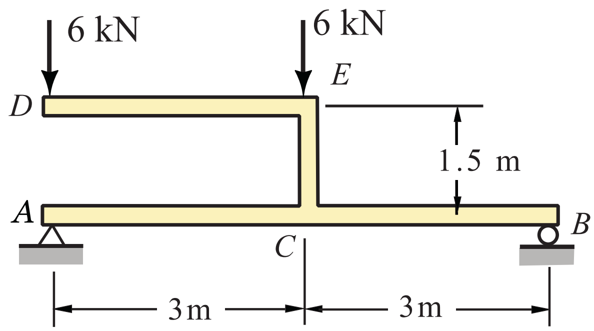
FUNDAMENTALS OF ENGINEERING

MECHANICS OF SOLIDS

Analysis of Determinate Frames

Problem: (Strength of Materials)



Support A : Hinge
Support B : Roller

The rigid bar CED is welded at point C to the steel beam AB as shown in the figure. The support at A is a pin (hinge) and the support at B is a roller.

Assuming that two concentrated loads are applied at *Dand E as* shown in the figure. Answer thr following questions:

(1) the support reaction (kN) at *A* is most nearly

(A) 10
(B) 6
(C) 8
(D) 9

(2) the support reaction (kN) at *B* is most nearly

(A) 2
(B) 3
(C) 5
(D) 7

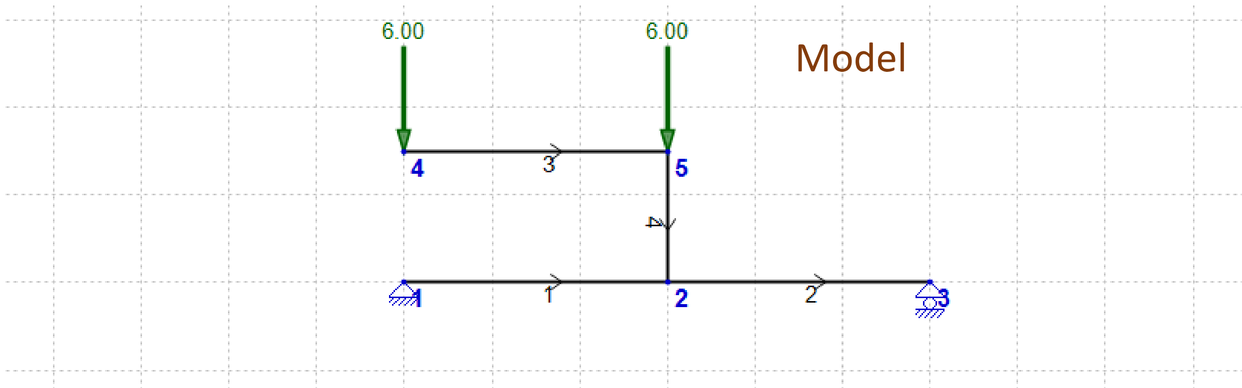
(3) the bending moment (kN.m) in member *EC* is most nearly

(A) 10
(B) 14
(C) 18
(D) 24

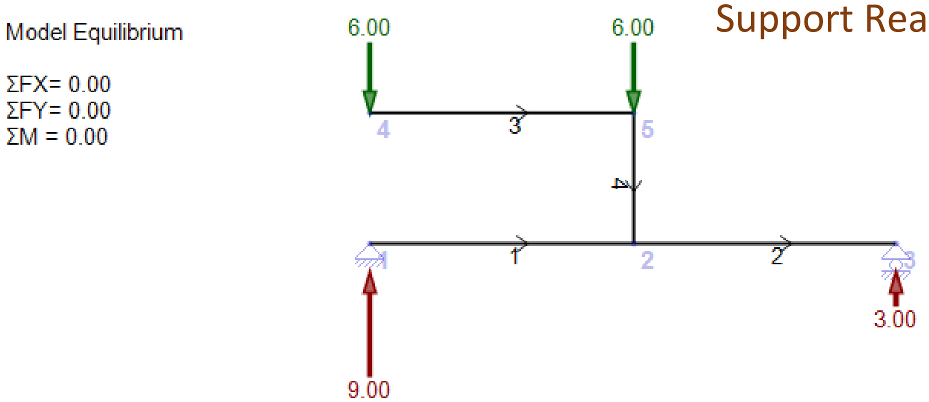
ANSWERS

Solution by Dr. Vagelis Plevris

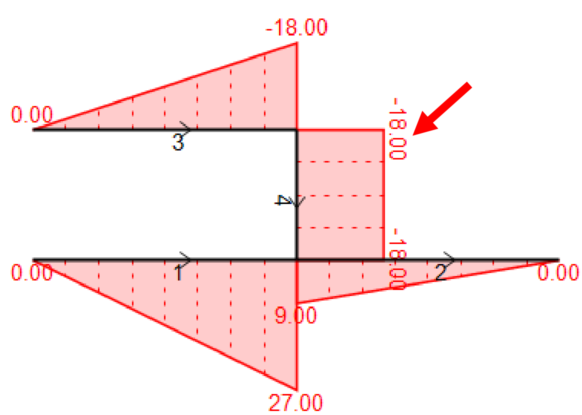
Model



Support Reactions



Bending Moment Diagram



Answers:

(1) D (A_y = 9 kN)

(2) B (B_y = 3 kN)

(3) C (M_{EC} = 18 kNm)

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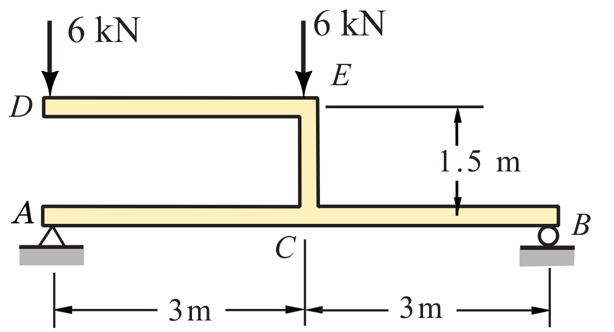
MECHANICS OF SOLIDS

Shear Force & Bending Moment Diagrams

Problem: (Strength of Materials)



Support *A* : Hinge
Support *B* : Roller

The rigid bar *CED* is welded at point *C* to the steel beam *AB* as shown in the figure. The support at *A* is a pin (hinge) and the support at *B* is a roller.

Assuming that two concentrated loads P=6k are applied at *D* and *E* as shown. Answer the following questions:

(1) The shear force diagram (*V*) of this determinate frame is composed of:

- (A) Two triangles
- (B) Two rectangles
- (C) Three rectangles
- (D) Two triangles and one rectangle

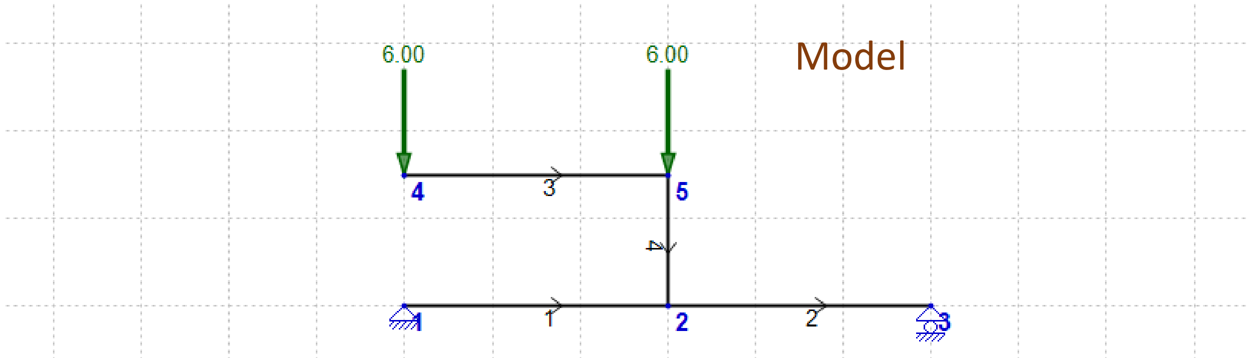
(2) The bending moment diagram (*M*) of this determinate frame is composed of:

- (A) Four triangles
- (B) Three triangles and one rectangle
- (C) One triangle and two rectangles
- (D) Two triangles and one rectangle

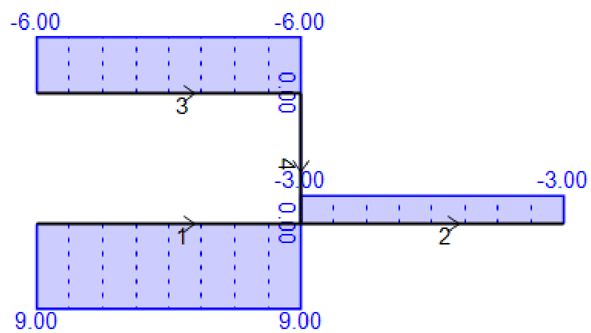
ANSWERS

Solution by Dr. Vagelis Plevris

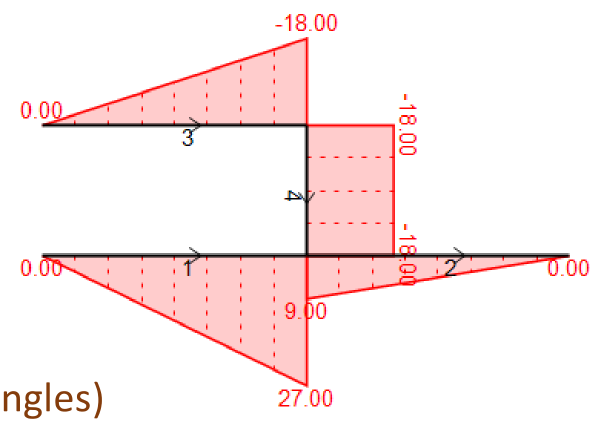
Model



Shear Force Diagram



Bending Moment Diagram



Answers:

(1) C (Three rectangles)

(2) B (Three triangles and one rectangle)

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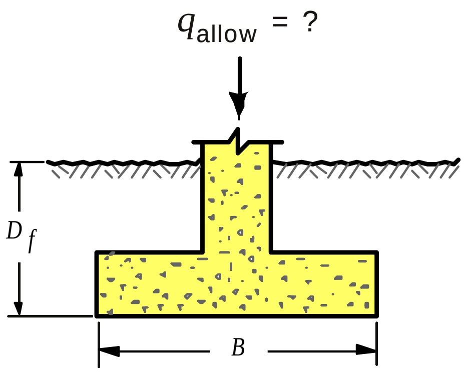
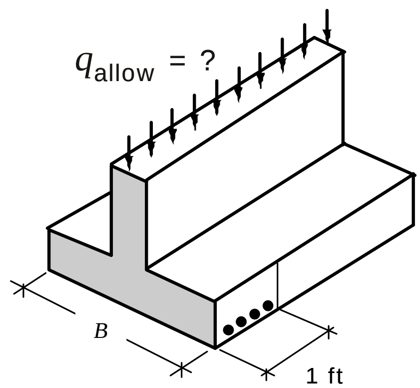
DESIGN OF CONCRETE STRUCTURES

WALL FOOTINGS (GENERAL SHEAR FAILURE)





Perspective view
Main Reinforcing
Steel Bars

Ultimate bearing capacity:

$$q_u = c' N_c + q N_q + \frac{1}{2} \gamma B N_\gamma$$

Allowable bearing capacity:

$$q_{allow} = \frac{q_u}{FS}$$

FS = Factor of safety (3 to 5)

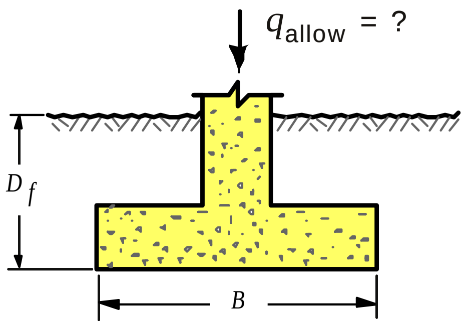
N_c , N_q , N_γ = Terzaghi bearing capacity factors

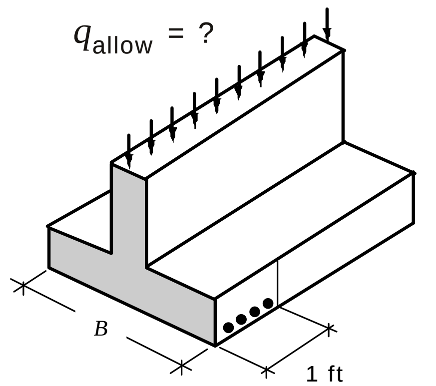
Terzaghi factors are function of ϕ' only and have <u>no</u> units!

q_u	=	ultimate bearing capacity (lb/ft^2, kips/ft^2, kN/m^2)
q_{allow}	=	allowable bearing capacity(lb/ft^2, kips/ft^2, kN/m^2)
ϕ'	=	soil friction angle (in degrees)
c'	=	cohesion of soil (psf, lb/ft^2, kips/ft^2, kN/m^2)
γ	=	unit weight of soil (pcf, lb/ft^3, kN/m^3)
q	=	equivalent surcharge ($q = \gamma D_f$)
B	=	width of footing (ft, m)
D_f	=	depth of footing (ft, m)

GEOTECHNICAL ENGINEERING

WALL FOOTINGS (LOCAL SHEAR FAILURE)





Perspective view
Main Reinforcing Steel Bars

Ultimate bearing capacity:

$$q_u = \frac{2}{3} c' N'_c + q N'_q + 0.5 \, \gamma B N'_\gamma$$

Allowable bearing capacity:

$$q_{allow} = \frac{q_u}{FS}$$

FS = Factor of safety (3 to 5)

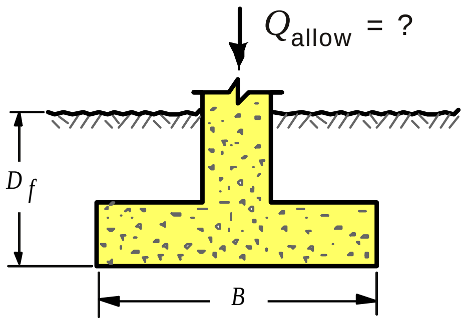
N'_c, N'_q, N'_γ = Terzaghi's modified bearing capacity factors

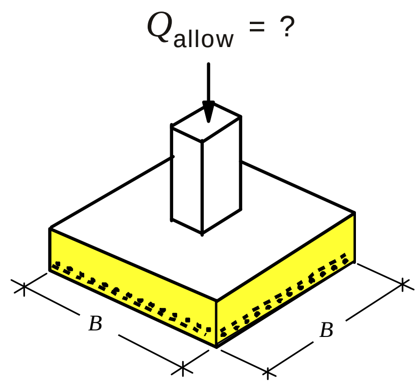
Terzaghi's factors are function of ϕ' only and have <u>no</u> units!

q_u = ultimate bearing capacity (lb/ft^2, $kips/ft^2$, kN/m^2)
q_{allow} = allowable bearing capacity(lb/ft^2, $kips/ft^2$, kN/m^2)
ϕ' = soil friction angle (in degrees)
c' = cohesion of soil (psf, lb/ft^2, $kips/ft^2$, kN/m^2)
γ = unit weight of soil (pcf, lb/ft^3, kN/m^3)
q = equivalent surcharge ($q = \gamma D_f$)
B = width of footing (ft, m)
D_f = depth of footing (ft, m)

GEOTECHNICAL ENGINEERING

SQUARE FOOTINGS / GENERAL SHEAR FAILURE





Perspective view
Reinforcing bars
in both direction

Ultimate bearing capacity:

$$q_u = 1.3\, c' N_c + q N_q + 0.4\, \gamma B N_\gamma$$

Allowable bearing capacity:

$$q_{allow} = \frac{q_u}{FS}$$

FS = Factor of safety (3 to 5)

Total Allowable Load:

$$Q_{allow} = q_{allow} B^2$$

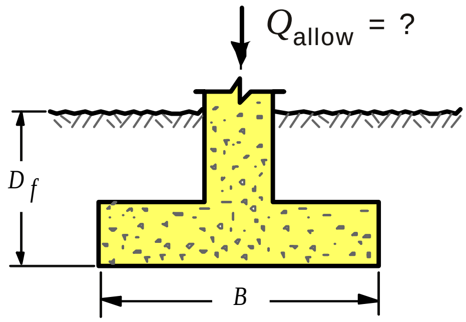
B = length of each side (ft, m)

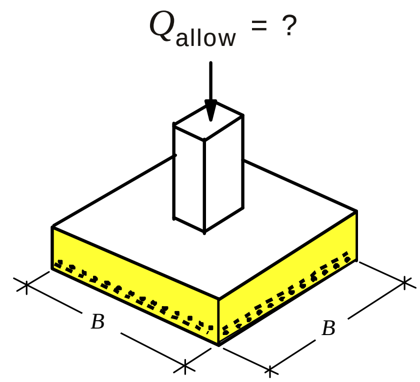
N_c , N_q , N_γ = Terzaghi bearing capacity factors

Terzaghi factors are function of ϕ' only and have no units!

q_u = ultimate bearing capacity (lb/ft^2, $kips/ft^2$, kN/m^2)
q_{allow} = allowable bearing capacity(lb/ft^2, $kips/ft^2$, kN/m^2)
ϕ' = soil friction angle (in degrees)
c' = cohesion of soil (psf, lb/ft^2, $kips/ft^2$, kN/m^2)
γ = unit weight of soil (pcf, lb/ft^3, kN/m^3)
q = equivalent surcharge ($q = \gamma D_f$)
B = length of each side of square footing (ft, m)
D_f = depth of footing (ft, m)

GEOTECHNICAL ENGINEERING
SQUARE FOOTINGS / LOCAL SHEAR FAILURE





Perspective view
Reinforcing bars
in both direction

Ultimate bearing capacity:

$$q_u = 0.867\, c' N'_c + q N'_q + 0.4\, \gamma B N'_\gamma$$

Allowable bearing capacity:

$$q_{allow} = \frac{q_u}{FS}$$

FS = Factor of safety (3 to 5)

Total Allowable Load:

$$Q_{allow} = q_{allow} B^2$$

B = length of each side (ft, m)

N'_c , N'_q , N'_γ = Terzaghi's modified bearing capacity factors

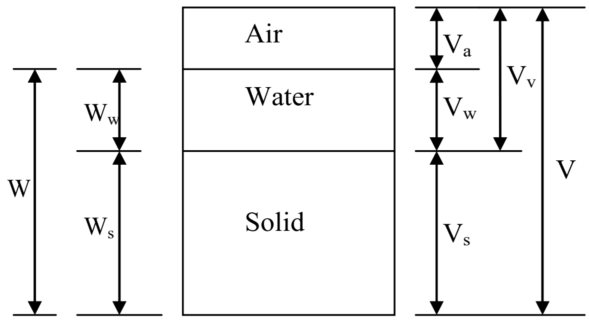
Terzaghi factors are function of ϕ' only and have no units!

q_u = ultimate bearing capacity (lb/ft^2, kips/ft^2, kN/m^2)
q_{allow} = allowable bearing capacity(lb/ft^2, kips/ft^2, kN/m^2)
ϕ' = soil friction angle (in degrees)
c' = cohesion of soil (psf, lb/ft^2, kips/ft^2, kN/m^2)
γ = unit weight of soil (pcf, lb/ft^3, kN/m^3)
q = equivalent surcharge ($q = \gamma D_f$)
B = length of each side of square footing (ft, m)
D_f = depth of footing (ft, m)

GEOTECHNICAL ENGINEERING

SOIL PROPERTIES & SOIL CLASSIFICATION

(1)



Specific gravity: G_s = 2.67
Unit weight: γ = 112 lb/ft^3
Water content (or moisture content):
w = 10.8%

For the soil shown above the following soil properties are given. Using the listed data, the void ratio (e) of soil is mostly near:

(A) 0.45
(B) 0.55
(C) 0.65
(D) 0.75

(2) Samples of a non-organic soil have been tested for its Atterburg limits and particle size distribution and the results are listed as follows:
LL = 35, PI = 20

Sieve analysis:

Sieve size	Percentage passing
No. 4	100
No. 200	44

Based on USCS system, this soil can be classified as:

(A) SC
(B) SM
(C) CL
(D) ML

(3) An embankment is required to be compacted to a dry unit weight of 116 lb/ft3. The borrow pit for this embankment project has soil with an in-place unit weight of 113 lb/ft3 and a moisture content of 9%.

How many cubic feet of soil must be excavated from the borrow pit to provide 1,000,000 ft3 of compacted embankment?

(A) 1,018,900
(B) 1,118,900
(C) 1,218,900
(D) 1,318,900

SOLUTIONS:

Solution: #1

Assume: $V = 1\, ft^3$

$$W = \gamma V = (112)(1) = 112\ lbs$$

$$w = \frac{W_w}{W_s} = 0.108 \text{ (given)}$$

$$W_w + W_s = W = 112\ lbs$$

$$W_w = 0.108(W_s)$$

Thus, $W_s = 101.1\ lbs$, and $W_w = 10.9\ lbs$

$$V_w = \frac{W_w}{\gamma_w} = \frac{10.9}{62.4} = 0.175\ ft^3$$

$$V_s = \frac{W_s}{\gamma_s} = \frac{W_s}{G_s \gamma_w} = \frac{101.1}{(2.67)(62.4)} = 0.607\ ft^3$$

$$V_a = V - V_s - V_w = 1 - 0.607 - 0.175 = 0.218\ ft^3$$

$$V_v = V - V_s = 1 - 0.607 = 0.393\ ft^3$$

$e = \frac{V_v}{V_s} = \frac{0.393}{0.607} = 0.65$, answer is (C)

Solution: #2

The percentage passing No. 200 sieve is 44%, less than 50%, so it is a coarse-grained soil. With more than 50% of coarse fraction passing No. 4 sieve (0% retained on No. 4 sieve), it is a sandy soil. With more than 44% fines (percentage passing No. 200), so it is either SM or SC. PI = 20 is greater than 7 and it is plotted above A line (LL = 35, PI = 20), so symbol is SC,

The answer is (A)

Solution: #3

The key for this problem is the solid weight (W_s) is the same for borrow pit and embankment. For the borrow pit, assume a unit volume:

$$V_{pit} = 1ft^3$$

$$W_{pit} = \gamma_{pit} V_{pit} = (113)(1) = 113\ lbs$$

$$w_{pit} = \frac{W_{w,pit}}{W_{s,pit}} = 0.09\ \text{(given)}$$

$$W_{w,pit} + W_{s,pit} = W_{pit} = 113\ lbs$$

$$\text{Thus, } W_{s,pit} = 103.67\ lbs$$

The solid weight (Ws) is the same for borrow pit and embankment:

$$W_{s,pit} = W_{s,embankment} = 103.67\ lbs$$

$$V_{t,embankment} = \frac{W_{s,embankment}}{\gamma_{d,embankment}} = \frac{103.67}{116} = 0.8937\ ft^3$$

Thus, 1 ft3 borrow pit can produce 0.8937 ft3 embankment soil

1 ft3 embankment soil requires 1/0.8937=1.1189 ft3 borrow pit

If we want 1,000,000 ft^3 embankment soil, we need:

1.1189×1,000,000 ft^3 =1,118,900 ft^3 borrow pit,

The answer is (B)

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