

FEBRUARY 2018

DR. Z's CORNER

*Conquering the FE & PE exams
Problems, Solutions & Applications*

This month's topics:

- **NCEES Calculator Policy for Current FE & PE Exams**
- **FE CIVIL Exam Topics & Number of Questions**
- **Analytical Geometry, Matrix Operations**
- **Analytical Geometry, Conic Sections**
- **Structures and Computational Methods, *Dr. Vagelis Plevris***
- **Construction Management, *Dr. Zeinab Farahmandfar***
- **Transportation Engineering, *Dr. Bryan Higgs***
- **Geotechnical Engineering, *Dr. Lei Wang***
- **Hydraulics, Open Channel Flow (Manning's Equation)**
- **Hydraulics, Applications of Manning's Equation**
- **Engineering Economics**
- **Semi Gravity Retaining Walls**
- **Mechanics of Materials, Centroids & Moments of Inertia**
- **Structures, Analysis of Determinate Beams & Trusses**
- **Structures, Deflections of Beams**
- **Structures, Indeterminate Beams**
- **Career Highlights of *Dr. Zeinab Farahmandfar***

TYPES OF CALCULATORS

ACCEPTABLE 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 are:

Casio: All fx-115 models. Any Casio calculator must contain fx-115 in its model name. Examples of acceptable Casio fx-115 models include (but are not limited to):

- fx-115 MS
- fx-115 MS Plus
- fx-115 MS SR
- fx-115 ES
- fx-115 ES Plus

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: The HP 33s and HP 35s models, but no others.

FUNDAMENTALS OF ENGINEERING

CIVIL EXAM TOPICS

Computer-Based Test (CBT)

Total Number of Questions: 110

Time: 6 hours

The new Civil FE Computer-Based Test (CBT) consists of 110 multiple-choice questions (Each problem has only one question) the examinee will have 6 hours to complete the test.

- **Mathematics (Approx. 9 questions)**
- **Probability and Statistics (5 questions)**
- **Computational Tools (5 questions)**
- **Ethics and Professional Practice (5 questions)**
- **Engineering Economics (5 questions)**
- **Statics (9 questions)**
- **Dynamics (5 questions)**
- **Mechanics of Materials (9 questions)**
- **Civil Engineering Materials (5 questions)**
- **Fluid Mechanics (5 questions)**
- **Hydraulics and Hydrologic Systems (10 questions)**
- **Structural Analysis (8 questions)**
- **Structural Design (8 questions)**
- **Geotechnical Engineering (12 questions)**
- **Transportation Engineering (10 questions)**
- **Environmental Engineering (8 questions)**
- **Construction (5 questions)**
- **Surveying (5 questions)**

FUNDAMENTALS OF ENGINEERING

DOMAIN: MATHEMATICS

CONIC SECTIONS

NCEES-Reference Handbook / 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:

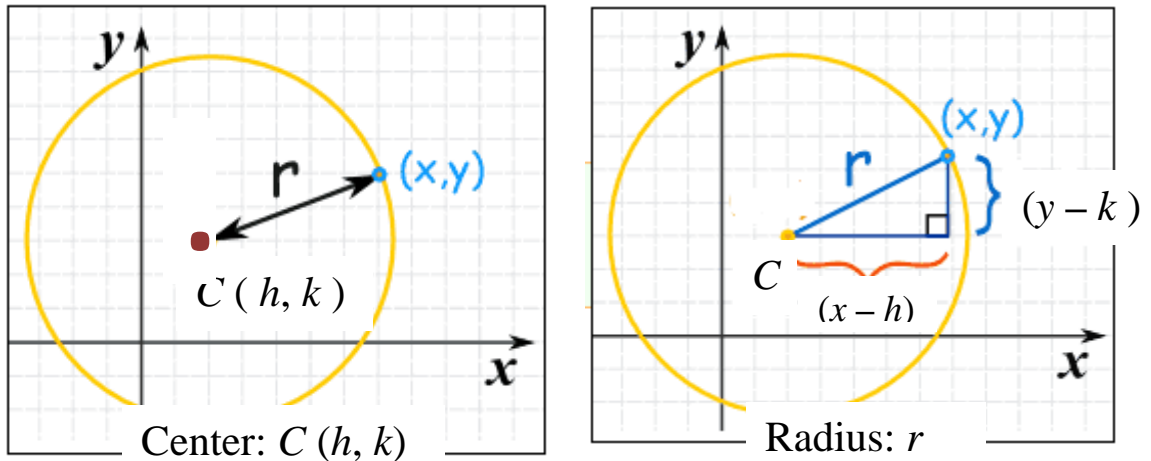
$$r = \sqrt{(x-h)^2 + (y-k)^2}$$

FUNDAMENTALS OF ENGINEERING

DOMAIN: MATHEMATICS

CIRCLE EQUATIONS

(NCEES-Ref Handbook / Page-27)



Standard form of a Circle Equation:

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

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

Example:

The equation of a circle with center at $C(4, -5)$ and a radius of 5 is:

- (A) $(x - 4)^2 + (y - 5)^2 = 5$
- (B) $(x - 7)^2 + (y - 5)^2 = 5$
- (C) $(x - 4)^2 + (y + 5)^2 = 25$
- (D) $(x + 4)^2 + (y - 5)^2 = 25$

FUNDAMENTALS OF ENGINEERING

MATRIX COMPUTATIONS

Problem

$$\mathbf{A} = \begin{bmatrix} 2 & 4 & -5 \\ -2 & 7 & 9 \\ -1 & 2 & 4 \end{bmatrix}$$

The matrix \mathbf{A} is given above, answer the following questions:

(1) the determinant of the above matrix is most nearly

- (A) 4
- (B) 3
- (C) 2
- (D) 1

(2) the inverse of matrix \mathbf{A} is most nearly, (\mathbf{A}^{-1})

(A) $\mathbf{A}^{-1} = \begin{bmatrix} 1/4 & 1/4 & -1/4 \\ 10/4 & 5/4 & 13/4 \\ -10/4 & -4/4 & 11/4 \end{bmatrix}$

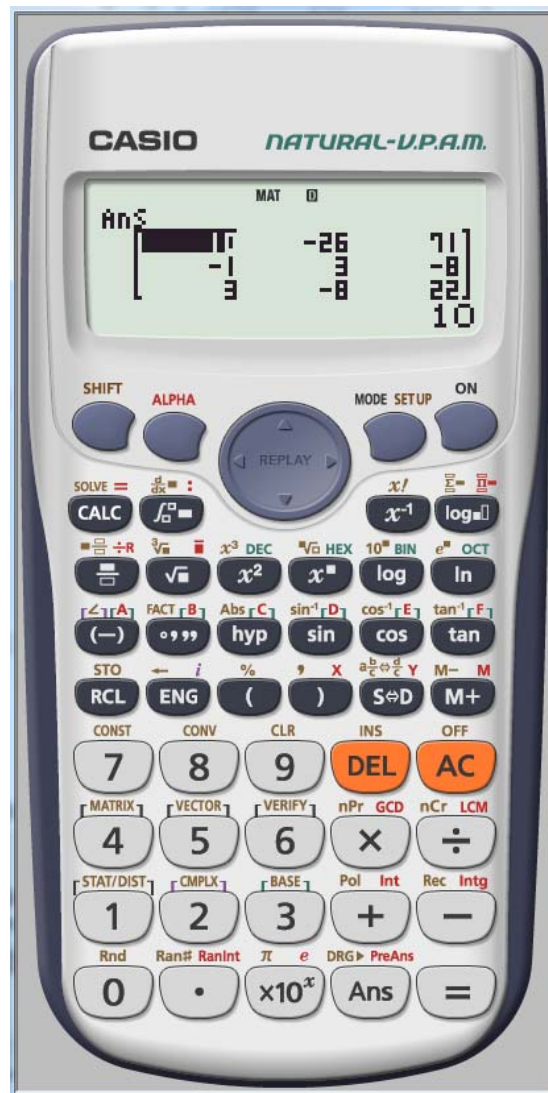
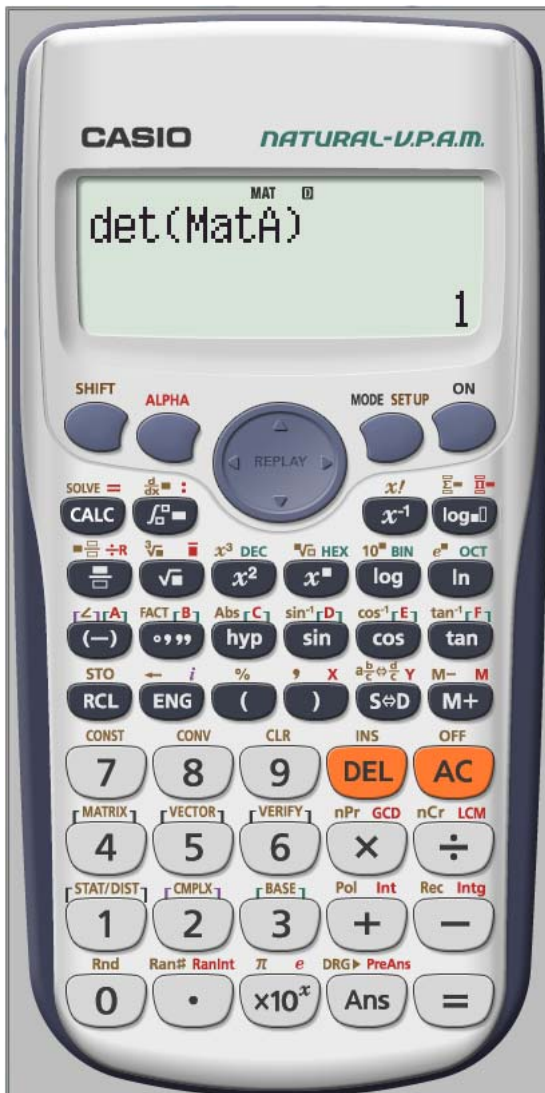
(B) $\mathbf{A}^{-1} = \begin{bmatrix} 2/3 & 1/3 & -1/6 \\ -11/3 & -7/3 & 13/3 \\ -17/3 & -8/3 & 32/3 \end{bmatrix}$

(C) $\mathbf{A}^{-1} = \begin{bmatrix} 10 & -26 & 71 \\ -1 & 3 & -8 \\ 3 & -8 & 22 \end{bmatrix}$

(D) $\mathbf{A}^{-1} = \begin{bmatrix} 2/3 & 1/2 & -1/2 \\ -11/2 & -3/2 & 13/2 \\ -17/2 & -6/5 & 21/2 \end{bmatrix}$

ANSWERS
BY
USING
TECHNOLOGY

USING TECHNOLOGY / MATRIX OPERATIONS



KEY LOG

$\boxed{\text{MODE}} \boxed{6} \boxed{1} \boxed{1} \boxed{2} \boxed{=}$ $\boxed{4} \boxed{=}$ $\boxed{-} \boxed{5} \boxed{=}$
 $\boxed{-} \boxed{2} \boxed{=}$ $\boxed{7} \boxed{=}$ $\boxed{9} \boxed{=}$ $\boxed{-} \boxed{1} \boxed{=}$ $\boxed{2} \boxed{=}$
 $\boxed{4} \boxed{=}$ $\boxed{\text{AC}}$ $\boxed{\text{SHIFT}} \boxed{4} \boxed{7} \boxed{\text{SHIFT}} \boxed{4} \boxed{3} \boxed{)} \boxed{=}$

You will see 1 as the answer for Det (A) as shown: **Answer is (D)**

$\boxed{\text{AC}} \boxed{\text{SHIFT}} \boxed{4} \boxed{3} \boxed{x^{-1}} \boxed{=}$

You will see the inverse of matrix (A) as shown: **Answer is (C)**

FUNDAMENTALS OF ENGINEERING

DOMAIN: MATHEMATICS

MATRICES & DETERMINANTS

Problem:

$$\mathbf{A} = \begin{bmatrix} 2 & -3 \\ 1 & -1 \end{bmatrix} \quad \mathbf{B} = \begin{bmatrix} 1 & 2 & -0 \\ 2 & -5 & -2 \end{bmatrix}$$

Using the matrices given above, answer the following questions:

(1) the determinant of the matrix **A** is most nearly

- (A) 4
- (B) -3
- (C) -2
- (D) 1

(2) the matrix product of **A** and **B** is most nearly, **A*B**

(A) $\mathbf{A*B} = \begin{bmatrix} -4 & 12 & -10 \\ 2 & -5 & -2 \end{bmatrix}$

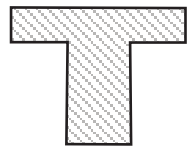
(B) $\mathbf{A*B} = \begin{bmatrix} -1 & 12 & -4 \\ 0 & -5 & -2 \end{bmatrix}$

(C) $\mathbf{A*B} = \begin{bmatrix} -4 & 19 & 6 \\ -1 & 7 & 2 \end{bmatrix}$

(D) $\mathbf{A*B} = \begin{bmatrix} -2 & 11 & -20 \\ 2 & 13 & 7 \end{bmatrix}$

CENTROIDS OF COMPOSITE AREAS

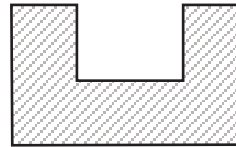
STRENGTH OF MATERIALS



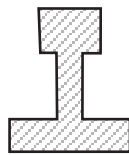
(1)



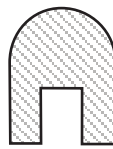
(2)



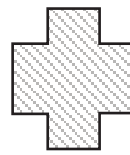
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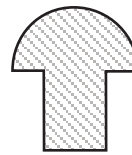
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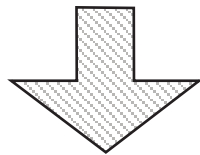
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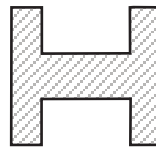
(6)



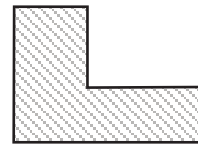
(7)



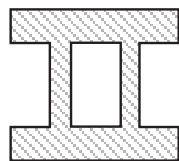
(8)



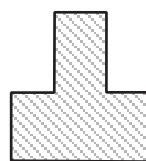
(9)



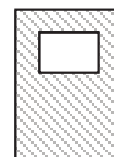
(10)



(11)



(12)



(13)

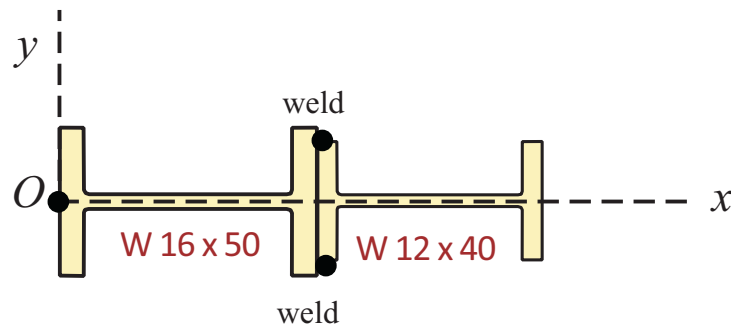
AXES OF SYMMETRY

VISUALLY LOCATING CENTROIDS

STATICS / MECHANICS OF SOLIDS

CENTROIDS & MOMENTS OF INERTIA

Problem



Two different-size W-Shapes are welded together as shown in the figure. Using the NCEES Reference handbook for section properties of W-shapes, answer the following questions:

(1) the distance \bar{x} (in.) of the centroid is most nearly

- (A) 11.1
- (B) 12.7
- (C) 13.1
- (D) 14.4

$$\bar{x} = ?$$

(2) the distance \bar{y} (in.) of the centroid is most nearly

- (A) 0
- (B) 5.2
- (C) 7.4
- (D) 9.3

$$\bar{y} = ?$$

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

- (A) 75.60
- (B) 81.30
- (C) 88.45
- (D) 96.20

$$I_{cx} = ?$$

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

- (A) 1530
- (B) 1932
- (C) 2261
- (D) 2940

$$I_{cy} = ?$$

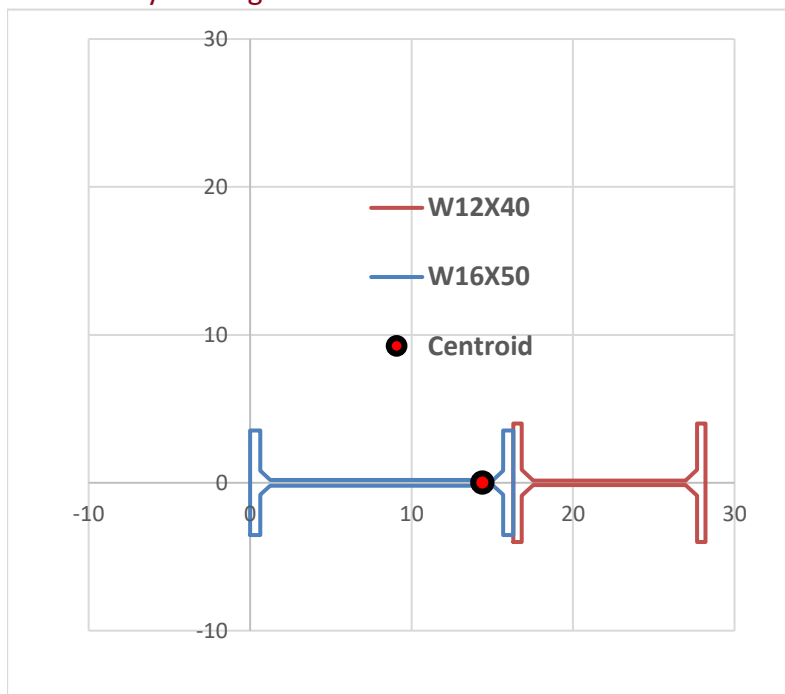
→
COMPLETE
SOLUTION

STATICS / MECHANICS OF SOLIDS

CENTROIDS & MOMENTS OF INERTIA

Problem: CCMC-50

Solution by Dr. Vagelis Plevris



LEFT SECTION (1) W16X50

ID	Quantity	Symbol	Value	Unit
4	Area	A	14.70	in ²
5	Depth	d	16.30	in
37	y - Moment of Inertia	I _y	659.00	in ⁴
41	x - Moment of Inertia	I _x	37.20	in ⁴

	A _i (in ²)	x _i (in)	A _i x _i (in ³)
1	14.70	8.15	119.81
2	11.70	22.25	260.33
Σ	26.40		380.13

RIGHT SECTION (2) W12X40

ID	Quantity	Symbol	Value	Unit
4	Area	A	11.70	in ²
5	Depth	d	11.90	in
37	y - Moment of Inertia	I _y	307.00	in ⁴
41	x - Moment of Inertia	I _x	44.10	in ⁴

	I _y (in ⁴)	A _i (in ²)	d _i (in)	A _i d _i ² (in ⁴)
1	659.00	14.70	6.25	574.01
2	307.00	11.70	7.85	721.19
Σ	966.00			1295.20

COMPOSITE SECTION PROPERTIES

Area	A =	26.40	in ²
Centroid - x	x _{bar} =	14.40	in
Centroid - y	y _{bar} =	0.00	in
x - Moment of Inertia	I _x =	81.30	in ⁴
y - Moment of Inertia	I _y =	2261.20	in ⁴
Total depth	d =	28.20	in
x - Radius of Gyration	r _x =	1.75	in
y - Radius of Gyration	r _y =	9.25	in

CCMC-50

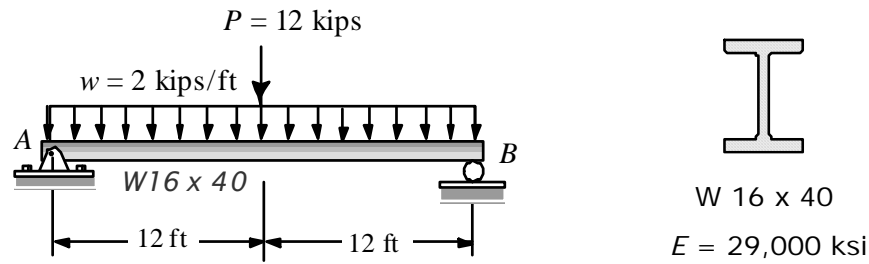
VPLEVRIS

FEB. 2018

ANSWERS:

1. D (14.40)
2. A (0)
3. B (81.30)
4. C (2261)

Problem: (Beam Deflections)



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) .

$$\begin{aligned}\delta_{\max} &= \frac{5}{384} \frac{wL^4}{EI} + \frac{1}{48} \frac{PL^3}{EI} = \frac{5}{384} \frac{(2.0)(24)^4}{(29,000)(518)} (12^3) + \frac{1}{48} \frac{(12)(24)^3}{(29,000)(518)} (12^3) \\ &= 0.994 + 0.397 = \underline{1.391 \text{ inches}}\end{aligned}$$

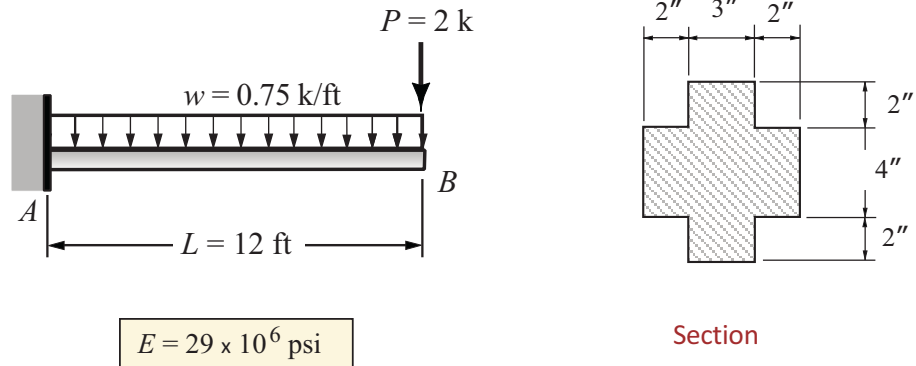
Finding the slope at support A:

$$\begin{aligned}\theta_A &= \frac{wL^3}{24EI} + \frac{PL^2}{16EI} = \frac{1}{24} \frac{(2.0)(24)^3}{(29,000)(518)} (12^2) + \frac{1}{16} \frac{(12)(24)^2}{(29,000)(518)} (12^2) \\ &= 0.01104 + 0.00414 = 0.01518 \text{ Radians} \\ &= \underline{0.01518 \text{ Radians}}\end{aligned}$$

MECHANICS OF SOLIDS

BEAM DEFLECTIONS

Problem: (Beam Deflections)

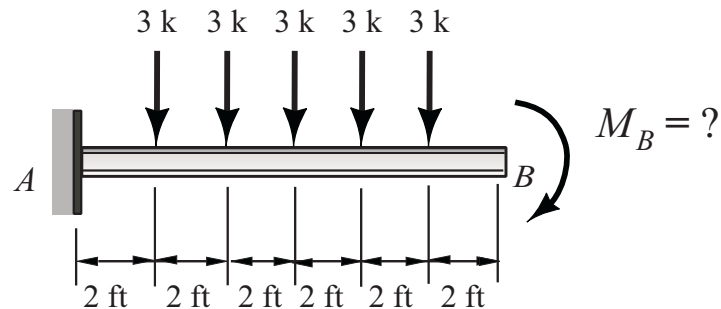


A cantilever beam is loaded as shown. The beam weight is included in the uniform load. Using the given cross-section and the modulus of elasticity answer the following questions:

- (1) the max. deflection (in.) of the beam is most nearly (δ_B)
 - (A) 1.18
 - (B) 1.24
 - (C) 1.56
 - (D) 2.15
- (2) the max. slope (rad.) at the free end is most nearly (θ_B)
 - (A) 0.012
 - (B) 0.015
 - (C) 0.019
 - (D) 0.022
- (3) the bending moment (k.ft) at the support is most nearly (M_A)
 - (A) 55
 - (B) 62
 - (C) 78
 - (D) 86

FUNDAMENTALS OF ENGINEERING
DETERMINATE BEAM ANALYSIS
STATICS & STRENGTH OF MATERIALS

Problem:



FE/PE
EXAM

Support *A* : Fixed

$$M_A = 110 \text{ ft-kip}$$

A cantilever beam is loaded as shown in the figure. Using the given loads answer the following questions:

- (1) Knowing that the magnitude of the moment at the fixed support *A* is 110 ft-kips, the magnitude of applied moment (ft-k) at the free end of the beam is most nearly

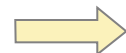
- (A) 10
- (B) 13
- (C) 18
- (D) 20

$$M_B = ?$$

- (2) The magnitude of the bending moment (ft-kips) at the mid-point of the beam (6 ft from *A*) is most nearly, $M_{\text{mid point}}$

- (A) 18
- (B) 28
- (C) 38
- (D) 40

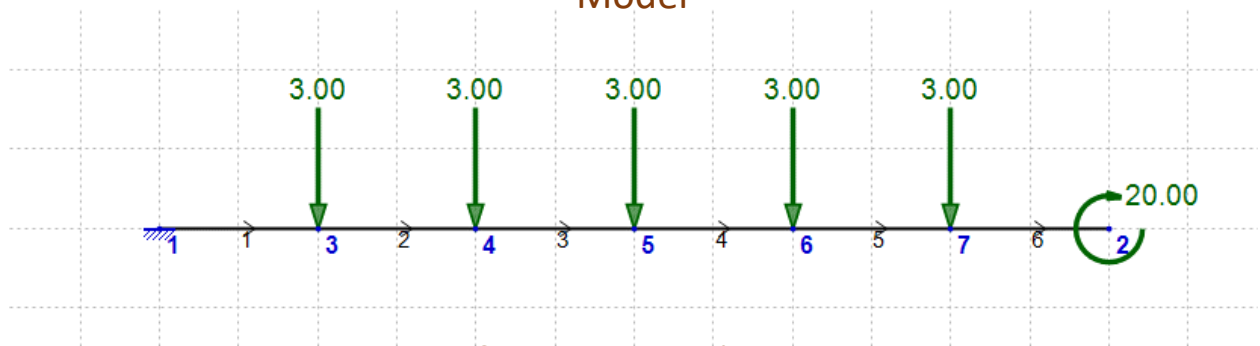
$$M_{\text{mid point}} = ?$$



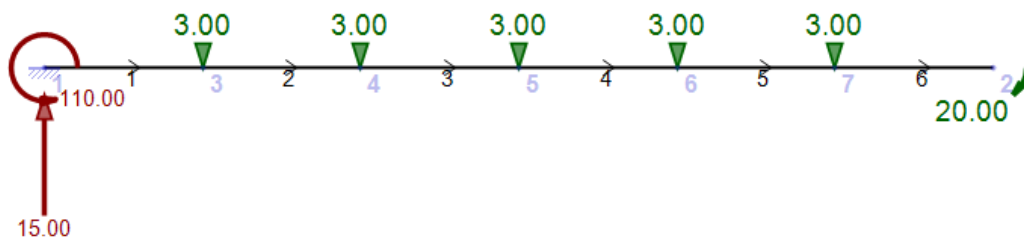
ANSWERS

Solution by Dr. Vagelis Plevris

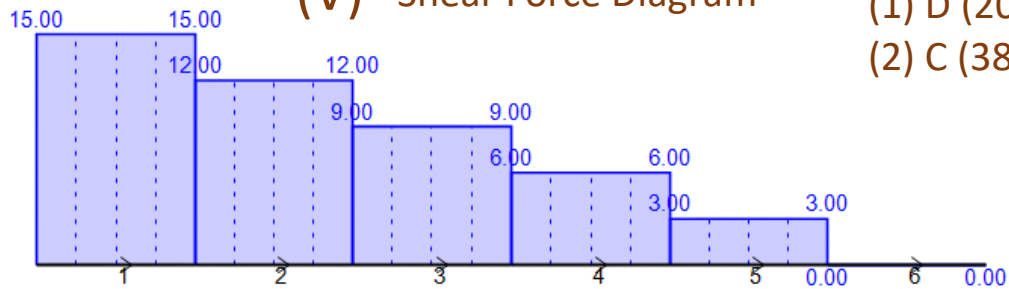
Model



Support Reactions



(V) Shear Force Diagram

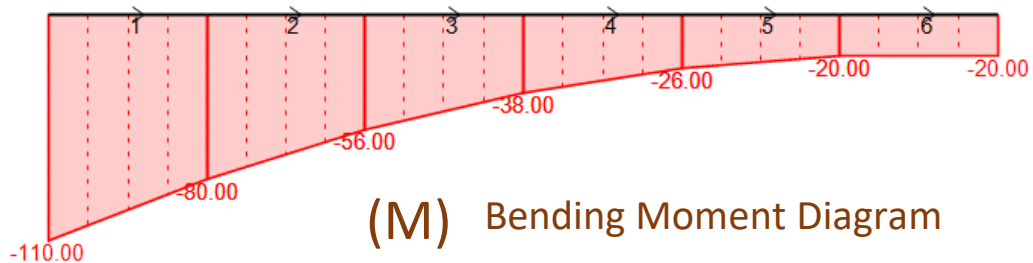


Answers:

(1) D (20)

(2) C (38)

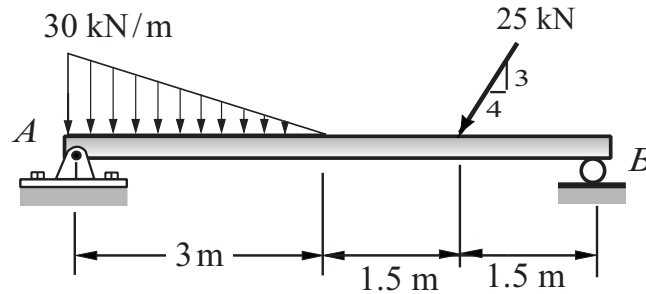
(M) Bending Moment Diagram



FUNDAMENTALS OF ENGINEERING
DETERMINATE BEAM ANALYSIS
STATICS & MECHANICS of MATERIALS

Problem:

FE/PE
EXAM



Support A : Hinge
Support B : Roller

Not to scale

A simple beam is loaded as shown in the figure. Using the given support conditions, answer the following questions:

(1) The vertical support reaction (kN) at B is most nearly, B_y

- (A) 18.75
- (B) 15.00
- (C) 13.25
- (D) 10.45

$$B_y = ?$$

(2) The vertical support reaction (kN) at A is most nearly, A_y

- (A) 30.25
- (B) 35.75
- (C) 38.25
- (D) 41.25

$$A_y = ?$$

(3) The bending moment (kN-m) at mid-point is most nearly, $M_{\text{mid-point}}$

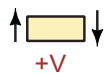
- (A) 26.25
- (B) 33.75
- (C) 42.25
- (D) 48.00



$$M_{\text{max}} = ?$$

(4) The shear force (kN) at the mid-point of AB is most nearly

- (A) 2.50
- (B) 3.75
- (C) 4.55
- (D) 5.00

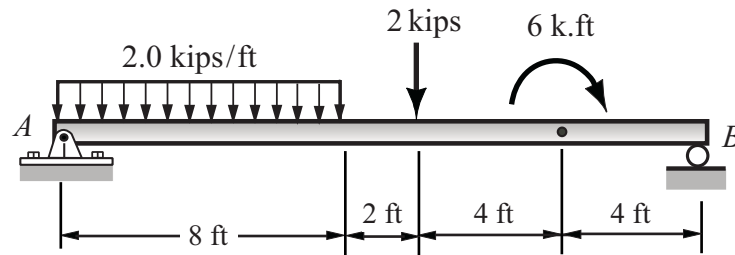


$$V_{\text{mid-point}} = ?$$

FUNDAMENTALS OF ENGINEERING

MECHANICS OF SOLIDS

Determinate Beam Analysis



FE/PE
EXAM

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

A determinate beam is loaded as shown in the figure. Using the given support conditions, answer the following questions:

(1) Magnitude of the support reaction (kips) at support *B* is most nearly, B_y

- (A) 3.5
- (B) 4.5
- (C) 5.0
- (D) 13.5

$$B_y = ?$$

(2) The maximum shear force (kips) in the beam is most nearly, V_{\max}

- (A) 10
- (B) 13
- (C) 17
- (D) 21

$$V_{\max} = ?$$

(3) The distance (ft) of the *Zero-Shear-Point* (ZSP) from support *A*

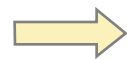
- (A) 3.5
- (B) 4.0
- (C) 5.5
- (D) 6.5

$$x = ?$$

(4) The maximum moment (ft-kips) in the beam is most nearly, M_{\max}

- (A) 37.40
- (B) 42.25
- (C) 52.26
- (D) 69.50

$$M_{\max} = ?$$



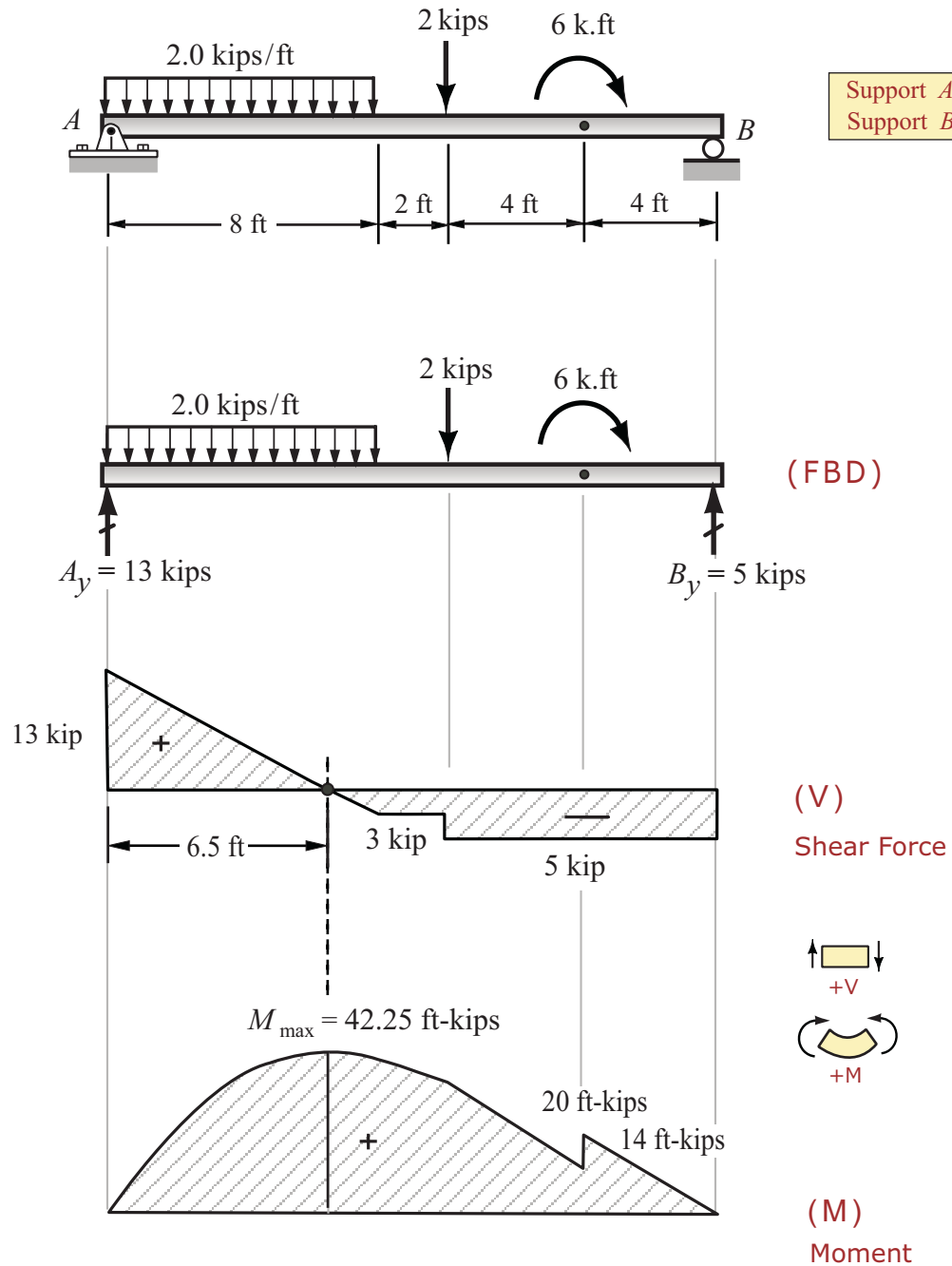
ANSWERS
SOLUTION

FUNDAMENTALS OF ENGINEERING

MECHANICS OF SOLIDS

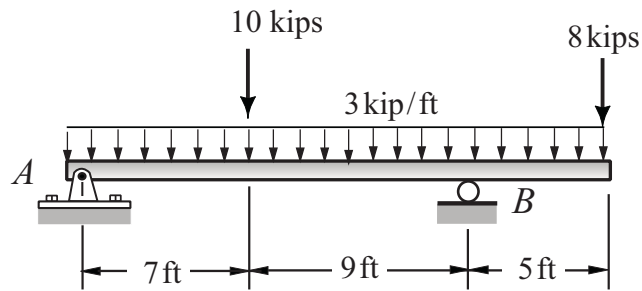
Shear Force & Bending Moment Diagrams

FE/PE
EXAM



FUNDAMENTALS OF ENGINEERING
SHEAR FORCE AND BENDING MOMENT
STATICS & STRENGTH OF MATERIALS

Problem:



FE/PE
EXAMS

Support *A* : Pin
Support *B* : Roller

An overhanging beam is loaded as shown. Using the given dimensions and support conditions, answer the following:

(1) The vertical support reaction (kips) at *B* is most nearly:

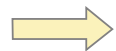
- (A) 48.8
- (B) 24.8
- (C) 42.4
- (D) 56.2

$$B_y = ?$$

(2) The absolute maximum bending moment (k-ft) in the beam is most nearly:

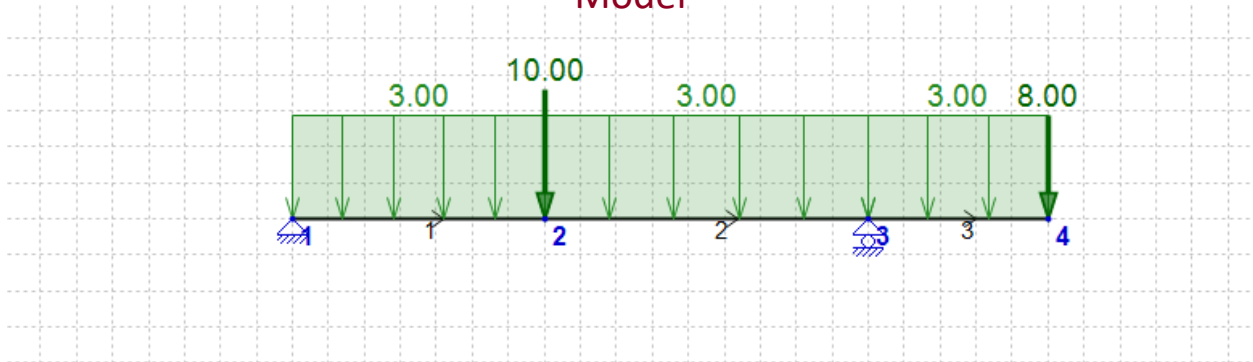
-
- (A) 100.0
 - (B) 77.5
 - (C) 90.4
 - (D) 108.3

$$M_{\max} = ?$$

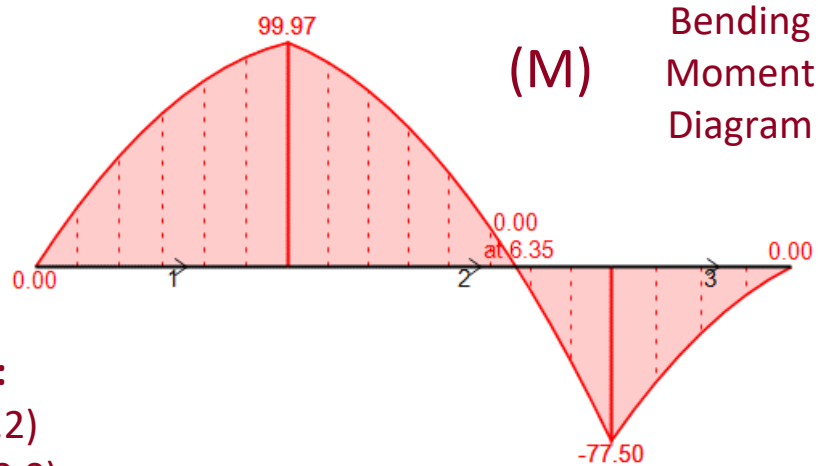
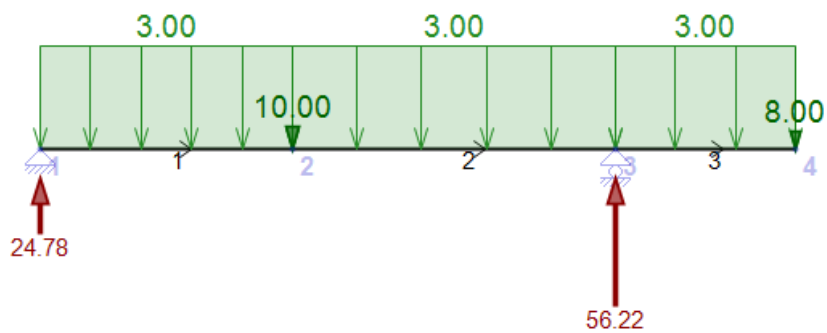


ANSWERS

Model



Support Reactions

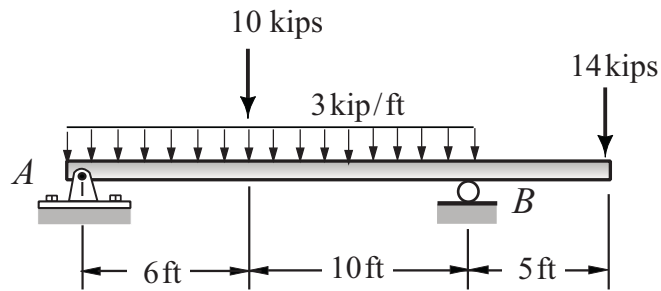


Answers:

- (1) D (56.2)
- (2) A (100.0)

FUNDAMENTALS OF ENGINEERING
SHEAR FORCE AND BENDING MOMENT
STATICS & STRENGTH OF MATERIALS

Problem:



FE/PE
EXAMS

Support A : Pin
Support B : Roller

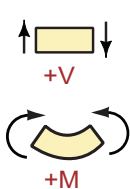
An overhanging beam is loaded as shown. Using the given dimensions and support conditions, answer the following:

(1) The vertical support reaction (kips) at *B* is most nearly:

- (A) 33.2
- (B) 46.1
- (C) 41.4
- (D) 25.9

$$B_y = ?$$

(2) The absolute maximum bending moment (k-ft) in the beam is most nearly:



- (A) 85.0
- (B) 92.5
- (C) 108.7
- (D) 101.3

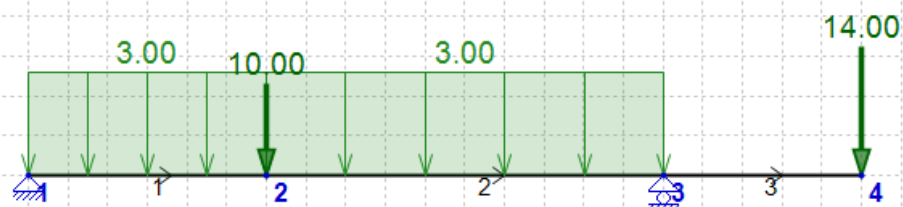
$$M_{\max} = ?$$



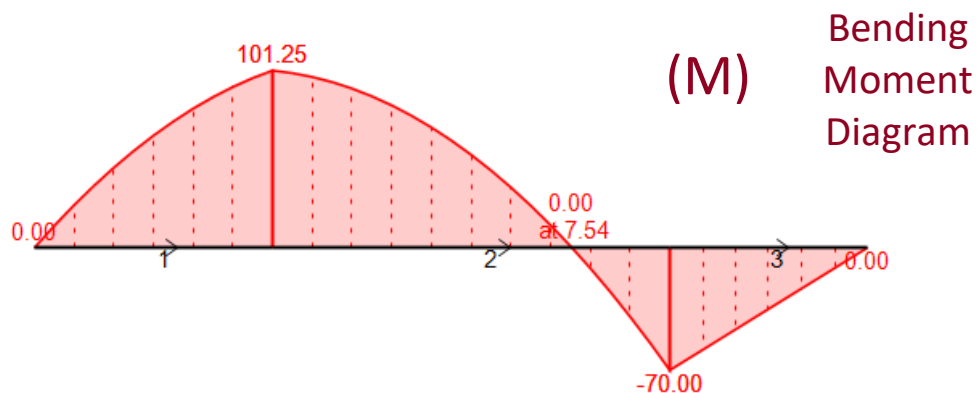
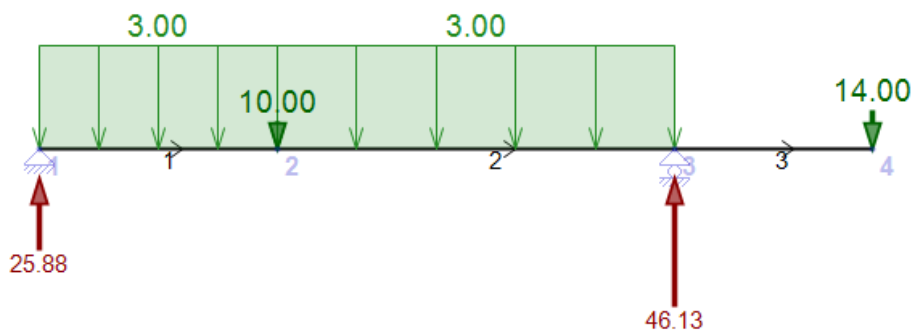
ANSWERS

Solution by Dr. Vagelis Plevris

Model



Support Reactions



Answers:

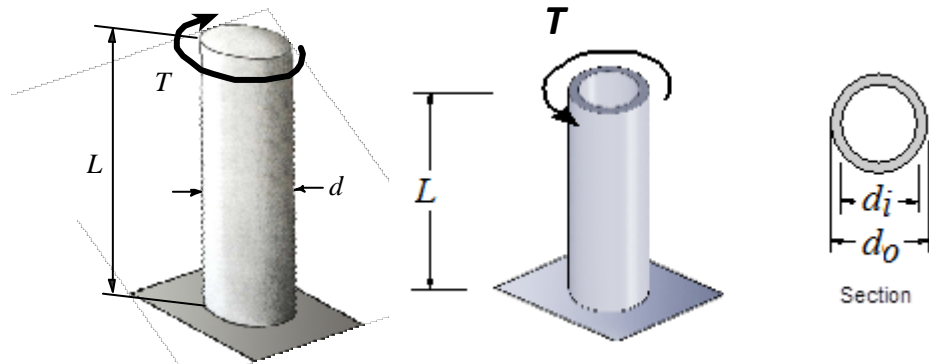
(1) B (46.1)

(2) D (101.3)

STRENGTH OF MATERIALS

TORSION

IMPORTANT FORMULAS



d_o : outside diameter

d_i : inside diameter

$$(1) \quad J = \frac{\pi d^4}{32} \quad J = \frac{\pi (d_o^4 - d_i^4)}{32}$$

$$(2) \quad T = \frac{\tau \cdot J}{r}$$

NCEES-Reference Handbook
Version 9.4

$$(3) \quad \phi = \frac{T \cdot L}{G \cdot J}$$

ϕ = total angle of twist (radians)

T = torque, torsional moment

L = length of shaft

J = polar moment of inertia

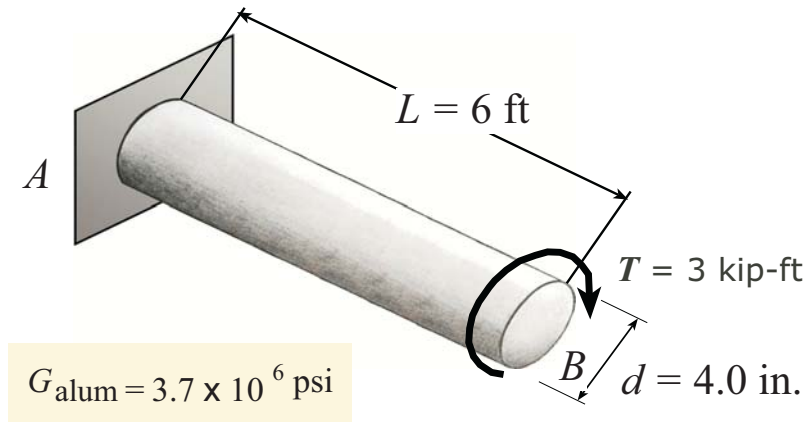
$$(4) \quad \tau_{\max} = \frac{T \cdot r}{J}$$

MECHANICS OF SOLIDS

TORSION

ANGLE OF TWIST

Problem: (Torsion)



- (1) A 4.0-in diameter solid aluminum shaft is loaded as shown. Using the listed data and the material properties the angle of twist (degrees) caused by $T = 3 \text{ kip-ft}$ torque is most nearly:

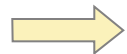
- (A) 1.20
- (B) 1.60
- (C) 2.10
- (D) 2.40

$$\phi_B = ?$$

- (2) If the given shaft is replaced by a hollow shaft with inside diameter of $d_i = 2.5 \text{ in.}$ and outside diameter of $d_o = 4.0 \text{ in.}$, the angle of twist (degrees) caused by the same torque $T = 3 \text{ kip-ft}$ is most nearly:

- (A) 1.59
- (B) 1.26
- (C) 1.88
- (D) 2.14

$$\phi_B = ?$$



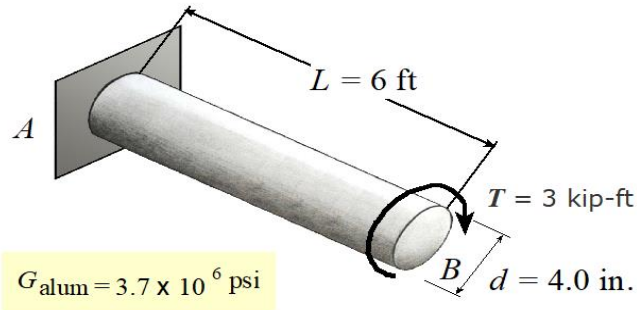
COMPLETE
SOLUTION

MECHANICS OF SOLIDS
TORSION
SHEARING STRESS FORMULA

Problem:

TOR-246

Solution in MS Excel



$L =$	6	ft
$d =$	4.0	in
$T =$	3	kip-ft
$G =$	3.70E+06	psi
$T =$	36	kip-in
$L =$	72	in
$G =$	3.70E+03	ksi

(1) Solid section

$J =$	25.133	in ⁴
$\phi =$	0.02787	rad
$\phi =$	1.60	deg

$$J = \frac{\pi d^4}{32}$$

$$\phi = \frac{T \cdot L}{G \cdot I_p}$$

(2) Hollow section

$d_o =$	4.0	in
$d_i =$	2.5	in

$$J = \frac{\pi (d_o^4 - d_i^4)}{32}$$

$J =$	21.298	in ⁴
$\phi =$	0.03289	rad
$\phi =$	1.88	deg

$$\phi = \frac{T \cdot L}{G \cdot I_p}$$

Answers:

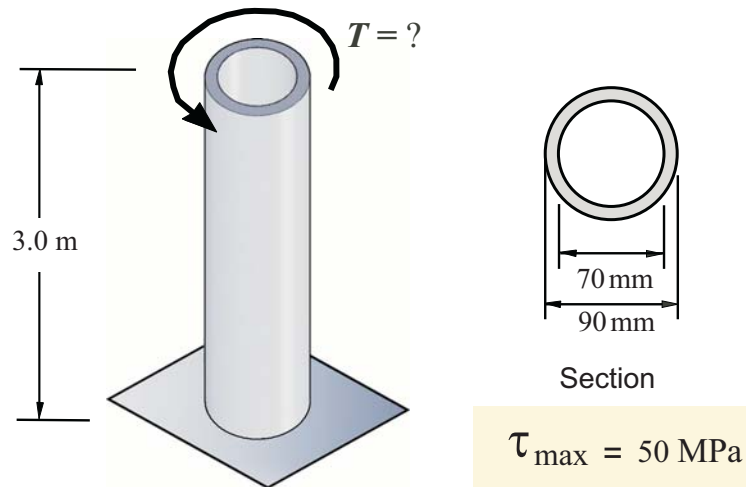
- (1) B (1.60)
 (2) C (1.88)

MECHANICS OF SOLIDS

TORSION

SHEARING STRESS FORMULA

Problem: (Torsion)



- (1) A hollow cylindrical shaft is loaded as shown. Using the listed data and the given maximum shearing stress, the torque T (kN.m) would be most nearly:

- (A) 2.85
- (B) 3.17
- (C) 3.71
- (D) 4.54

$$T = ?$$

- (2) Now assume the given shaft is replaced by a solid shaft. Also the torque that you found from above, will be used for this question. Assuming that the cross-sectional area will be same as above, then max. shearing stress (MPa) is most nearly:

- (A) 127.67
- (B) 112.16
- (C) 99.86
- (D) 134.67

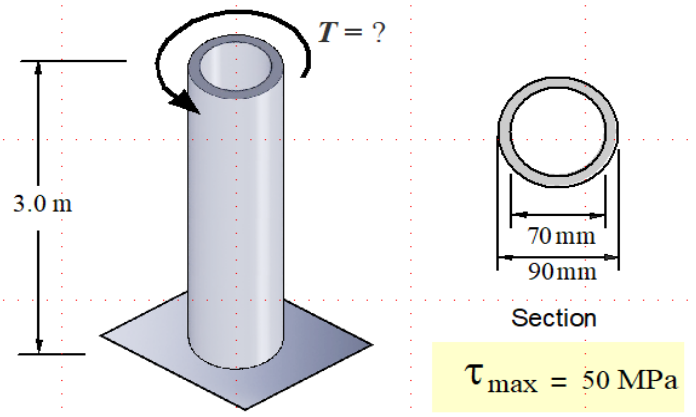
$$\tau_{\max} = ?$$



COMPLETE
SOLUTION

MECHANICS OF SOLIDS
TORSION
SHEARING STRESS FORMULA

Problem: **TOR-250** **Solution in MS Excel**



$$\begin{aligned} L &= 3.0 \text{ m} \\ d_o &= 90 \text{ mm} \\ d_i &= 70 \text{ mm} \\ \tau_{\max} &= 50 \text{ MPa} \end{aligned}$$

Answers:
 (1) D (4.54)
 (2) A (127.67)

(1) Hollow (tube) section

$$\begin{aligned} d_o &= 0.09 \text{ m} \\ d_i &= 0.07 \text{ m} \\ r &= 0.045 \text{ m} \\ \tau_{\max} &= 50000 \text{ kPa} \\ J_{\text{tube}} &= 4.08\text{E-}06 \text{ m}^4 \\ \mathbf{T} &= \mathbf{4.54 \text{ kN}\cdot\text{m}} \end{aligned}$$

$$J_{\text{tube}} = \frac{\pi (d_o^4 - d_i^4)}{32}$$

$$T = \frac{\tau_{\max} \cdot J}{r}$$

(2) Solid section

$$\begin{aligned} A &= 2513.3 \text{ mm}^2 \\ d &= 56.57 \text{ mm} \\ d &= 5.657\text{E-}02 \text{ m} \\ r &= 2.828\text{E-}02 \text{ m} \\ J_{\text{solid}} &= 1.005\text{E-}06 \text{ m}^4 \\ \tau_{\max} &= 1.277\text{E+}05 \text{ kPa} \\ \mathbf{T_{\max}} &= \mathbf{127.67 \text{ MPa}} \end{aligned}$$

$$A_{\text{tube}} = \frac{\pi (d_o^2 - d_i^2)}{4}$$

$$A_{\text{solid}} = \frac{\pi d^2}{4} \Rightarrow d = \sqrt{\frac{4A}{\pi}}$$

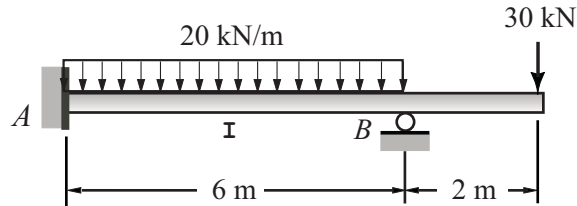
$$J_{\text{solid}} = \frac{\pi d^4}{32}$$

$$\tau_{\max} = \frac{T \cdot r}{J}$$

STRUCTURAL ANALYSIS

INDETERMINATE BEAMS

FE/PE
EXAM



Support A : Fixed
Support B : Roller

An indeterminate beam is loaded as shown in the figure. Using the given support conditions, answer the following questions:

(1) The bending moment (kN.m) at support A is most nearly, M_A

- (A) - 45.5
- (B) - 50.0
- (C) - 55.5
- (D) - 60.0



(2) The magnitude (kN) of the vertical support reaction at A is, A_y

- (A) 55
- (B) 60
- (C) 75
- (D) 80

(3) The location (m) of the zero-shear point from A

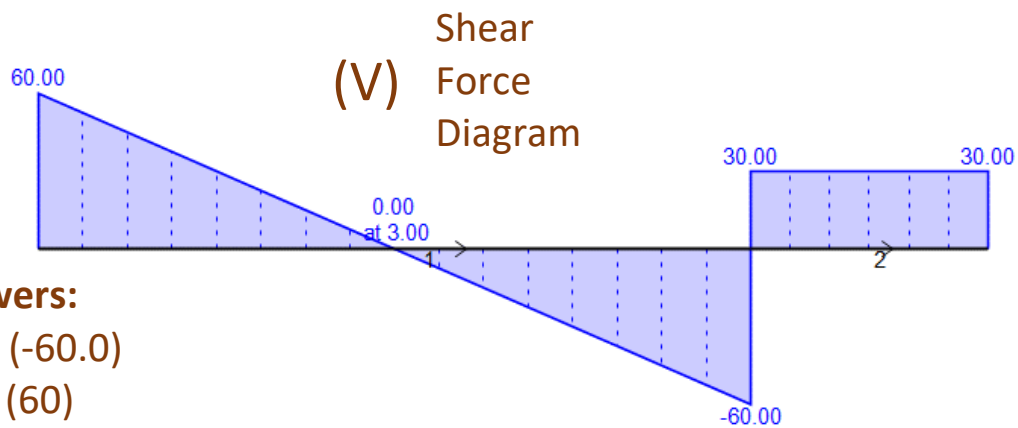
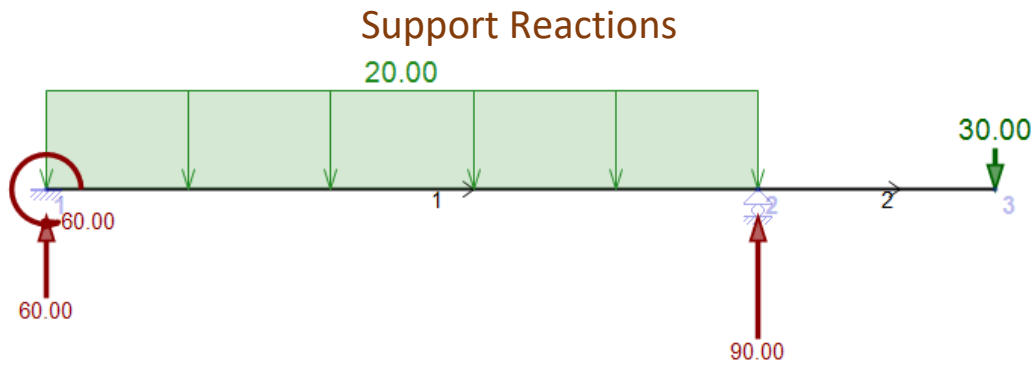
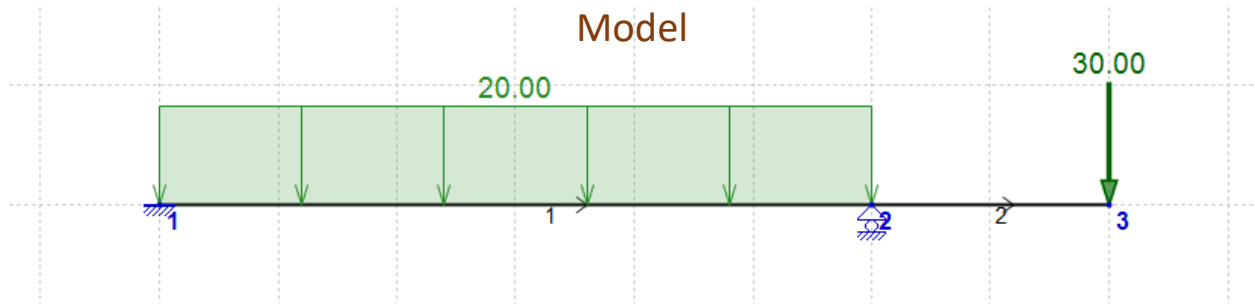
- (A) 2.00
- (B) 2.50
- (C) 3.00
- (D) 3.50

(4) The maximum positive moment (kN.m) in AB is most nearly

- (A) 40.0
- (B) 30.0
- (C) 25.5
- (D) 20.6

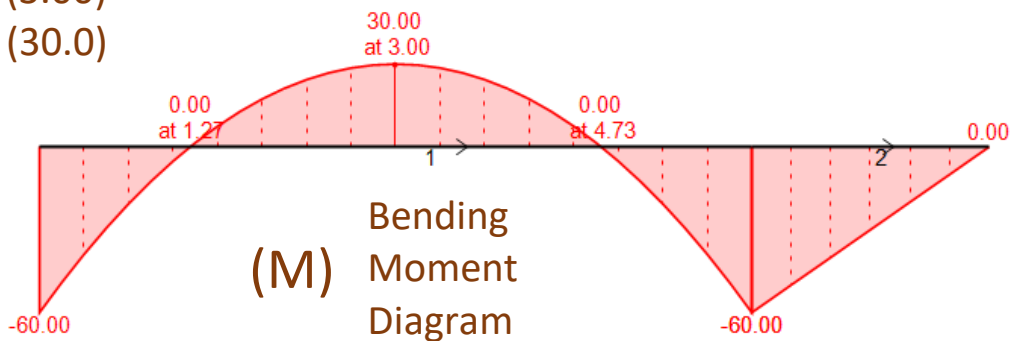


Solution by Dr. Vagelis Plevris



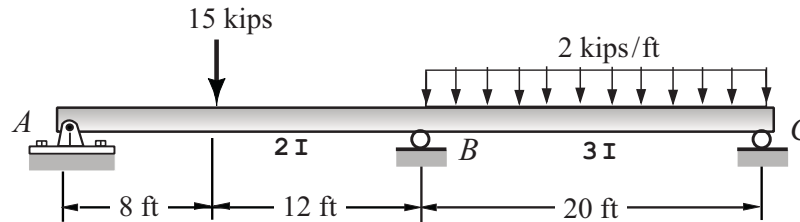
Answers:

- (1) D (-60.0)
- (2) B (60)
- (3) C (3.00)
- (4) B (30.0)



STRUCTURAL ANALYSIS

INDETERMINATE BEAM ANALYSIS



FE/PE
EXAM

$$M_B = -70.24 \text{ ft-kips}$$



Support A : Pin
Support B : Roller
Support C : Roller

An indeterminate beam is loaded as shown in the figure. Knowing that the bending moment at support B is given as listed, answer the following questions:

(1) The magnitude of the support reaction at A is most nearly, A_y

- (A) 7.27 kips
- (B) 4.18 kips
- (C) 6.29 kips
- (D) 5.49 kips

$$A_y = ?$$

(2) The magnitude of the support reaction at C is most nearly, C_y

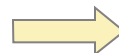
- (A) 18.24 kips
- (B) 17.38 kips
- (C) 16.49 kips
- (D) 15.49 kips

$$C_y = ?$$

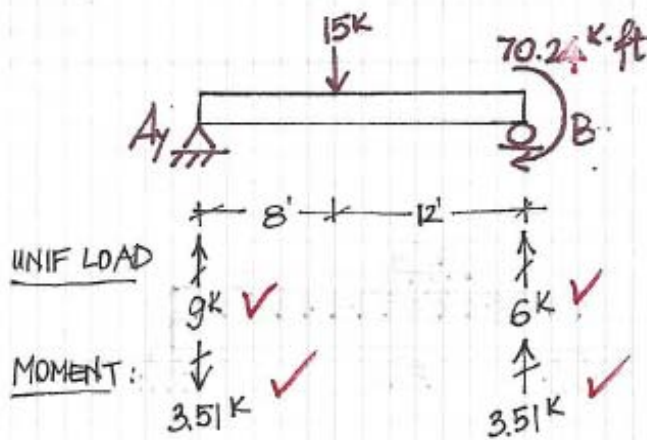
(3) The magnitude of the support reaction at B is most nearly, B_y

- (A) 42.52 kips
- (B) 33.02 kips
- (C) 26.48 kips
- (D) 20.05 kips

$$B_y = ?$$

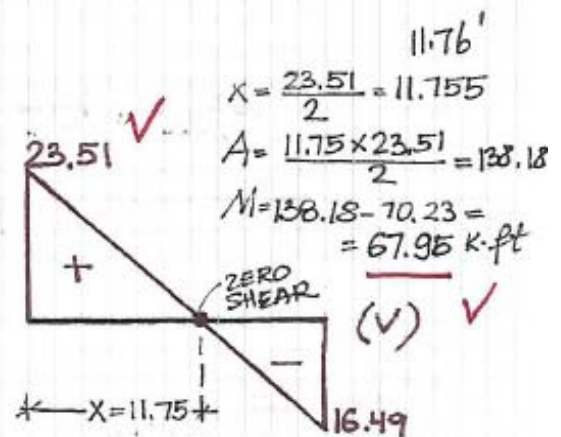
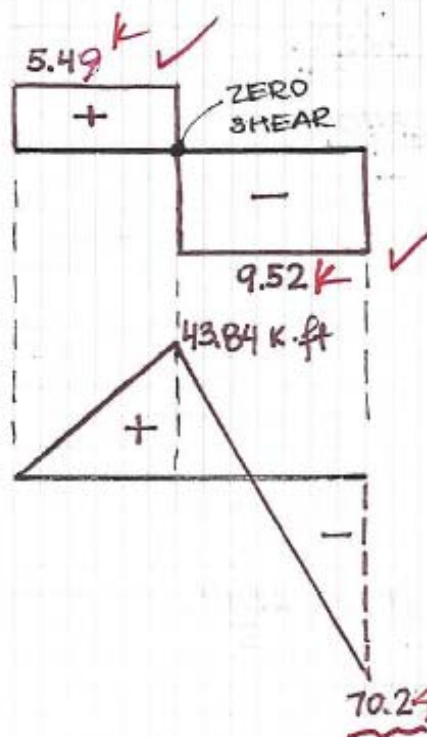
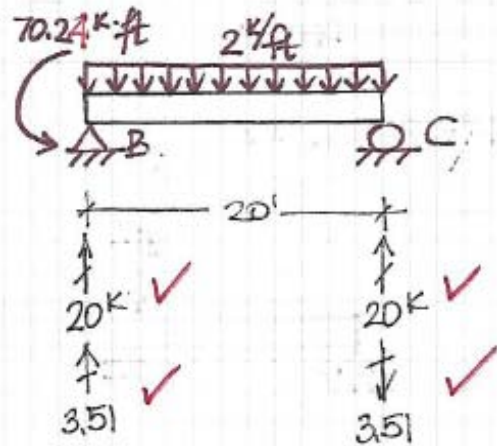


COMPLETE
SOLUTION



$$A_y = (15) \left(\frac{12}{20} \right) = 9K \uparrow \quad \checkmark$$

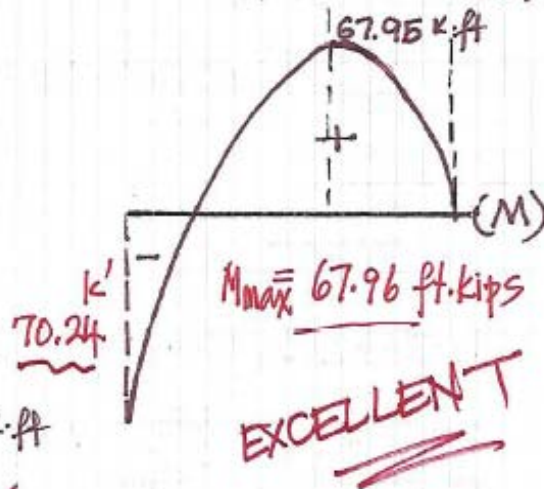
$$B_y = (15) \left(\frac{8}{20} \right) = 6K \uparrow \quad \checkmark$$



$$x = \frac{23.51}{2} = 11.755$$

$$A = \frac{11.75 \times 23.51}{2} = 138.18$$

$$M = 138.18 - 70.23 = 67.95 \text{ K·ft}$$

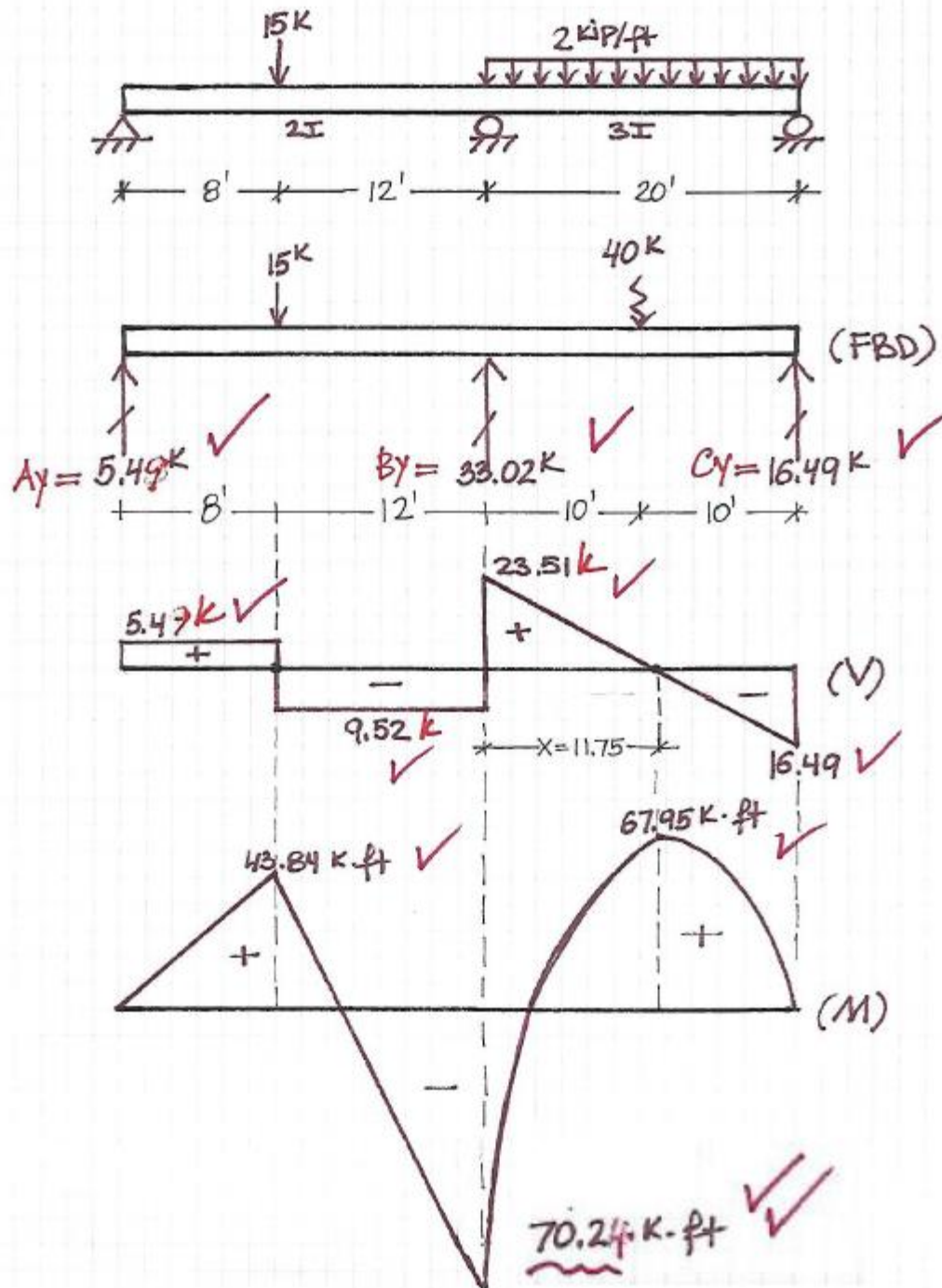


$$A_y = 9K - 3.51K = 5.49K \uparrow \quad \checkmark$$

$$B_y = 6K + 3.51K + 20K + 3.51K = 33.02K \uparrow \quad \checkmark$$

$$C_y = 20K - 3.51K = 16.49K \uparrow \quad \checkmark$$

PROBLEM # 3

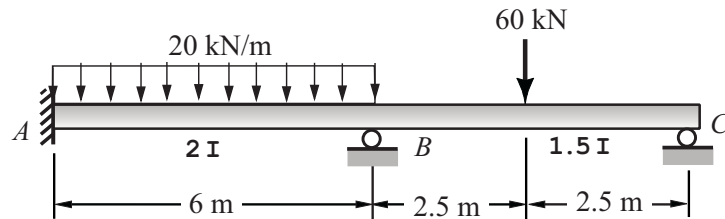


PROFESSIONAL ENGINEERING (P.E.)

STRUCTURAL ANALYSIS

Indeterminate Beams

Problem: (Indeterminate Beams)



Support *A* : Fixed
Support *B* : Roller
Support *C* : Roller

An indeterminate beam is loaded as shown in the figure. Using the given support conditions, answer the following questions:

(1) The bending moment (kN.m) at support *A* is most nearly, M_A

- (A) - 39.32
- (B) - 53.35
- (C) - 61.12
- (D) - 84.23



(2) The bending moment (kN.m) at support *B* is most nearly, M_B

- (A) - 35.40
- (B) - 57.76
- (C) - 68.75
- (D) - 82.77



(3) The magnitude (kN) of the vertical support reaction at *B* is, B_y

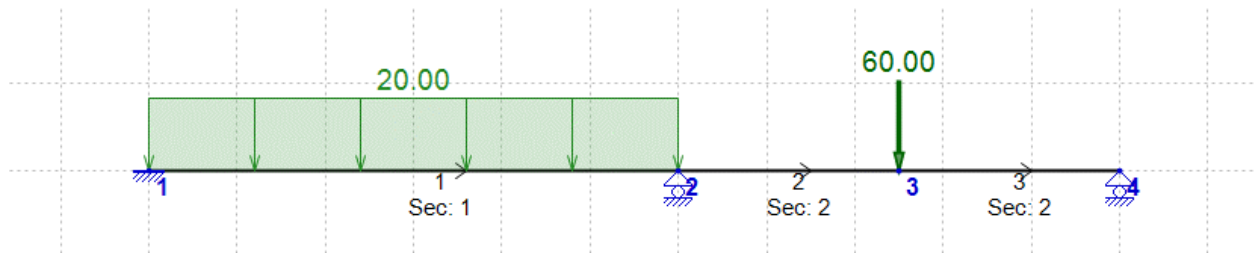
- (A) 74
- (B) 83
- (C) 92
- (D) 101

(4) The bending moment (kN.m) under the 60-kN load is most nearly

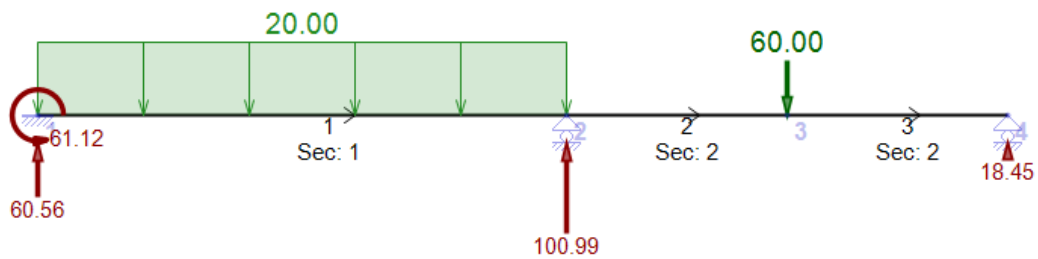
- (A) 37.25
- (B) 46.12
- (C) 55.70
- (D) 66.85

Solution by Dr. Vagelis Plevris

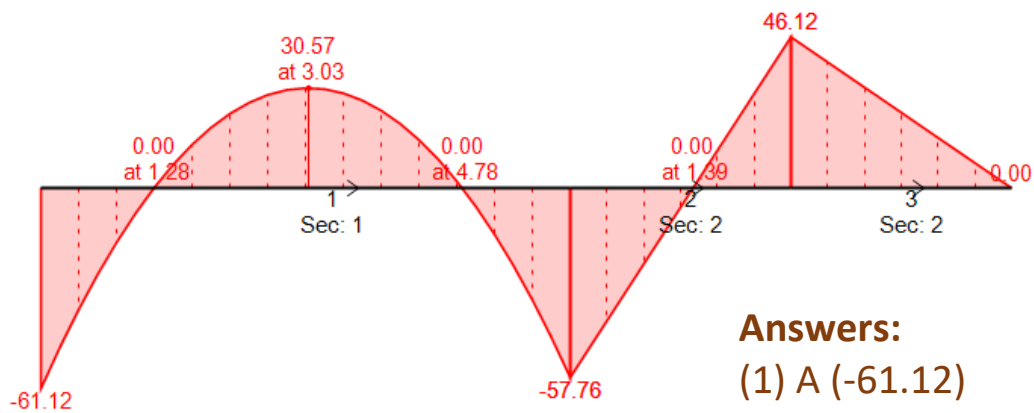
Model



Support Reactions



(M) Bending Moment Diagram

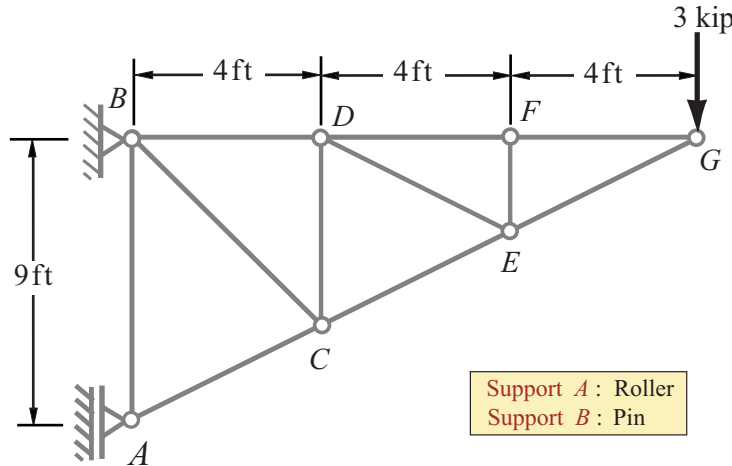


Answers:

- (1) A (-61.12)
- (2) B (-57.76)
- (3) D (101)
- (4) B (46.62)

FUNDAMENTALS OF ENGINEERING (F.E.)
PROFESSIONAL ENGINEERING (P.E.)
MECHANICS OF MATERIALS
PLANE TRUSS SYSTEMS

Problem: (Plane Truss)



**FE/PE
EXAM
STRUCTURAL
ANALYSIS**

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

(1) the total number of *zero-force* members is most nearly

- (A) 1
- (B) 2
- (C) 4
- (D) 5

$$n_{ZFM} = ?$$

(2) the magnitude of the member force (kips) in *BD* is most nearly

- (A) 7.5
- (B) 6.0
- (C) 5.5
- (D) 4.0

$$F_{BD} = ?$$

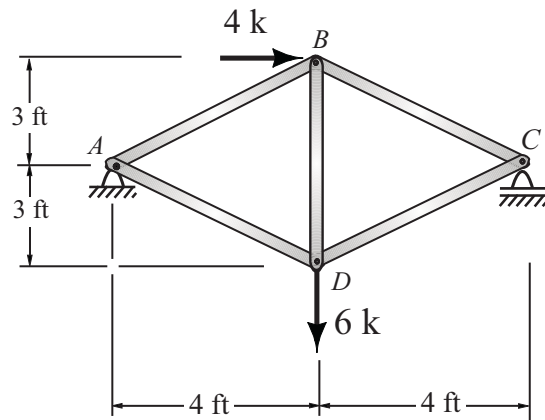
(3) the magnitude of the member force (kips) in *AC* is most nearly

- (A) 3.0
- (B) 4.5
- (C) 5.0
- (D) 6.5

$$F_{AC} = ?$$

FUNDAMENTALS OF ENGINEERING

STATICS / PLANE TRUSSES



FE/PE
EXAM

Support A : Pin
Support C : Roller

A plane truss system is loaded as shown. Using the listed data and the loads, determine:

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

- (A) 5.25 (C)
- (B) 1.25 (T)
- (C) 3.00 (C)
- (D) 3.75 (T)

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

- (A) 4.25 (C)
- (B) 3.75 (T)
- (C) 2.75 (C)
- (D) 6.75 (T)

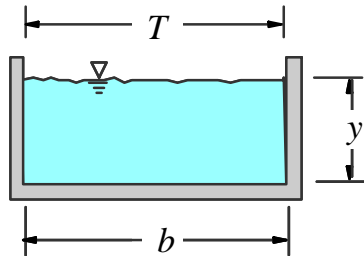
(3) the magnitude of the member force (kN) in member BD is most nearly:

- (A) 1.50 (T)
- (B) 2.25 (T)
- (C) 3.75 (C)
- (D) 5.25 (C)

GEOMETRIC ELEMENTS OF CHANNEL SECTIONS

OPEN CHANNEL FLOW

Rectangular Channel



Area

$$A = b \cdot y$$

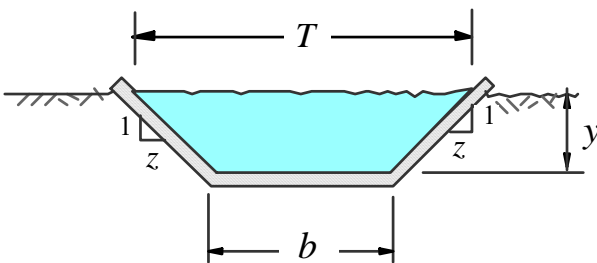
Wetted Perimeter

$$P = b + 2 \cdot y$$

Top Width

$$T = b$$

Trapezoidal Channel



Area

$$A = (b + z y) y$$

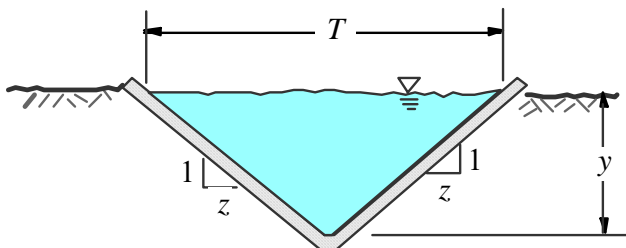
Wetted Perimeter

$$P = b + 2 y (1 + z^2)^{1/2}$$

Top Width

$$T = b + 2 z y$$

Triangular Channel



Area

$$A = z y^2$$

Wetted Perimeter

$$P = 2 y (1 + z^2)^{1/2}$$

Top Width

$$T = 2 z y$$

Hydraulic Radius

$$R_H = \frac{A}{P}$$

MANNING'S EQUATION

The Manning's Equation is an empirical formula estimating the average velocity of a liquid (water) flowing in a conduit that does not completely enclose the liquid like open channel flow. All flow in open channels is driven by gravity.

NCEES Reference Handbook, Version 9.4, page-167:

$$Q = \frac{K}{n} A R_H^{2/3} S^{1/2}$$

Manning's Equation

$$Q = \frac{1}{n} A R_H^{2/3} S^{1/2}$$

SI units ($K = 1$)

$$Q = \frac{1.486}{n} A R_H^{2/3} S^{1/2}$$

USCS units ($K = 1.486$)

$$V = \frac{Q}{A}$$

Q = Flow rate, quantity of flow, discharge (ft³/sec or m³/sec)

K = values are listed above

A = cross-sectional area of flow (ft² or m²)

R_H = hydraulic radius ($R_H = A/P$), (feet or meters)

P = wetted perimeter (feet or meters)

S = gradient, slope of hydraulic surface (ft/ft or m/m)

n = Manning's roughness coefficient, roughness factor

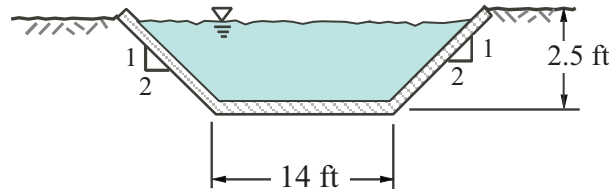
V = Flow velocity (ft/sec or m/sec)

FUNDAMENTALS OF ENGINEERING & PROFESSIONAL ENGINEERING

WATER RESOURCES

OPEN CHANNEL FLOW / MANNING'S EQUATION

Problem:



FE/PE
EXAM
WATER
RESOURCES

Side slopes of trapezoid 2:1 (as shown)

Gradient (slope) of the channel = 1.8%

Manning's roughness coefficient: ($n = 0.015$)

A concrete trapezoidal channel has a bottom width of 14 ft as shown in the figure. Knowing that the channel is on a 1.8 % slope and is flowing at a depth of 2.5 ft throughout its length, answer the following questions:

(1) The hydraulic radius (ft) of the channel is most nearly:

- (A) 1.9
- (B) 2.3
- (C) 2.7
- (D) 2.9

$$R_H = ?$$

(2) The quantity of flow (discharge) (ft^3/sec) is most nearly:

- (A) 587
- (B) 776
- (C) 815
- (D) 964

$$Q = ?$$

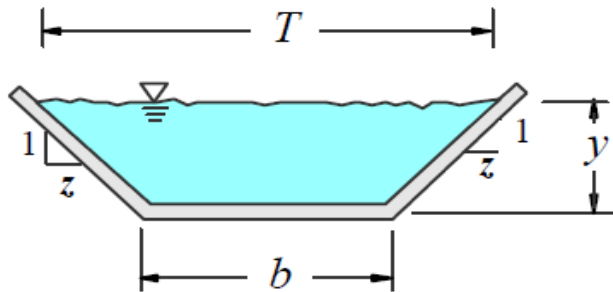
(3) The flow velocity (ft/sec) is most nearly:

- (A) 30
- (B) 26
- (C) 20
- (D) 18

$$V = ?$$

FUNDAMENTALS OF ENGINEERING & PROFESSIONAL ENGINEERING
WATER RESOURCES
OPEN CHANNEL FLOW / MANNING'S EQUATION

Problem: **HYDR-485** **Solution in MS Excel**



$S = 1.8\%$
 $n = 0.015$
 $b = 14$ ft
 $y = 2.5$ ft
 Side slopes $z = 2$:1

$$P = b + 2y(1 + z^2)^{1/2}$$

$P = 25.18$ ft (Wetted Perimeter)

Area = 47.50 ft²

$$A = (b + zy) \cdot y$$

$R_H = 1.89$ ft
 (A) Answer

$$R_H = \frac{\text{Area}}{\text{Perimeter}}$$

$$Q = \frac{1.486}{n} A \cdot R_H^{2/3} \cdot S^{1/2}$$

USCS Units
 (K=1.486)

$Q = 963.86$ ft³/sec
 (D) Answer

$V = 20.3$ ft/sec
 (C) Answer

$$V = \frac{Q}{A}$$

ENGINEERING ECONOMICS PROBLEMS

FUTURE WORTH & PRESENT WORTH

The simplest problems to solve in engineering economic analysis are those which involve finding the value of a single amount of money at an earlier or later date than that which is given. Such problems involve finding the **future worth (F)** of a specified **present amount (P)**, or vice versa. These problems involve using the following two equations:

$$F = P (1 + i)^n$$

$$P = F (1 + i)^{-n}$$

F: future sum of money

P: present sum of money

i: interest rate (%)

n: time (period), mostly years

Standard factor notations

$$F = P (F/P, i, n) = P \cdot (Factor)$$

$$P = F (P/F, i, n) = F \cdot (Factor)$$

Tabulated Interest Factors (NCEES-Reference Handbook, Ver. 9.4)

i = 0.5%, 1.0%, 1.5%, 2.0%, 4%, 6%, 8%, 10%, 12%, 18%

i = **1.5%** and **2%** (NCEES-RH / Page 134)

i = **4%** and **6%** (NCEES-RH / Page 135)

i = **8%** and **10%** (NCEES-RH / Page 136)

i = **12%** and **18%** (NCEES-RH / Page 137)

FUNDAMENTALS OF ENGINEERING

ENGINEERING ECONOMICS

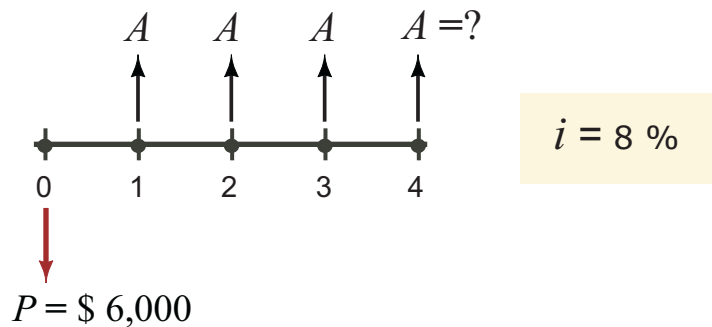
Problem: (Future Worth)

Patricia, an engineering student, deposits \$5,000 into a money market account which pays 8% interest per year. The amount that would be in her account at the end of 10 years is most nearly?

- (A) \$ 9,430
- (B) \$ 10,795
- (C) \$ 12,627
- (D) \$ 13,375

$$F = ?$$

Problem: (Present Worth) / HK



A copying machine costs \$6,000 and has a life of 4 years. Knowing that the interest rate is 8% compounded annually, the amount of money that will be saved every year to recover the cost of the capital invested in it is most nearly?

- (A) \$ 1326
- (B) \$ 1525
- (C) \$ 1634
- (D) \$ 1811

$$A = ?$$

FUNDAMENTALS OF ENGINEERING

ENGINEERING ECONOMICS

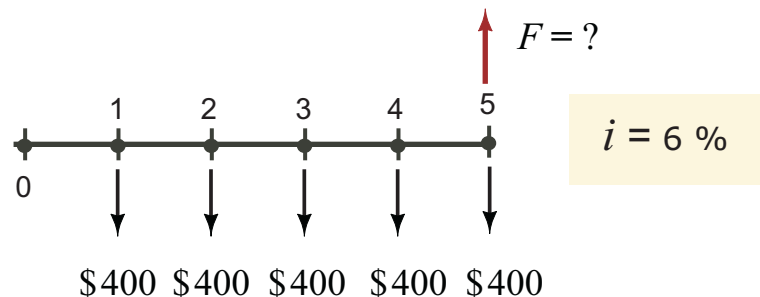
Problem: (Single Payment Present Worth)

Patricia, an engineering student, wishes to have \$1200 in a savings account at the end of 4 years. If the bank pays 6% interest annually the amount that she must put into her saving's account is most nearly:

- (A) \$ 690
- (B) \$ 715
- (C) \$ 858
- (D) \$ 950

$$P = ?$$

Problem: (Uniform Series Compound Amount)



Rachel deposits \$400 in a money market account at the end of each year for 5 years. The bank pays 6% interest, compounded annually. The amount of money that she can withdraw immediately after the fifth deposit is most nearly:

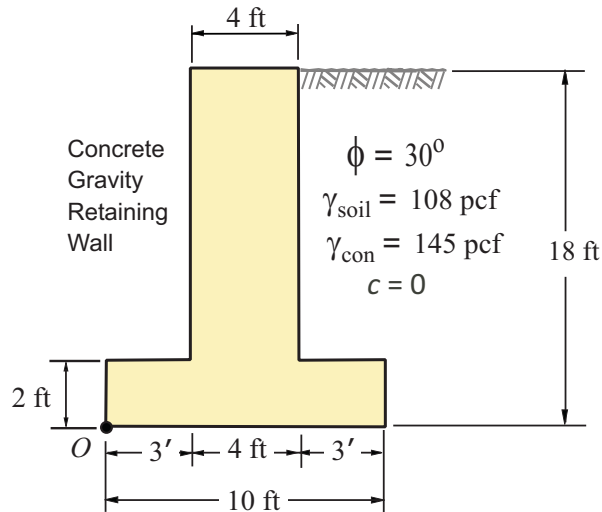
- (A) \$ 2026
- (B) \$ 2255
- (C) \$ 2635
- (D) \$ 2815

$$F = ?$$

**FUNDAMENTALS OF ENGINEERING (F.E.)
PROFESSIONAL ENGINEERING (P.E.)**

GRAVITY RETAINING WALLS

Problem:



The dimensions of a concrete gravity retaining wall is given as shown. Knowing that *Rankine active earth pressure* will be used in the computations and the wall friction will be disregarded, answer the following:

(1) The *overturning moment* (ft.kip/ft) about the toe at *O* is most nearly:

- (A) 24.45
- (B) 34.96
- (C) 46.32
- (D) 57.25

$$M_{ot} = ?$$

(2) The *stabilizing moment* (ft.kip/ft) about the toe at *O* is most nearly:

- (A) 16.79
- (B) 85.78
- (C) 92.48
- (D) 104.96

$$M_{\text{stab}} = ?$$

(3) The *factor of safety* against overturning about the toe at *O* is most nearly:

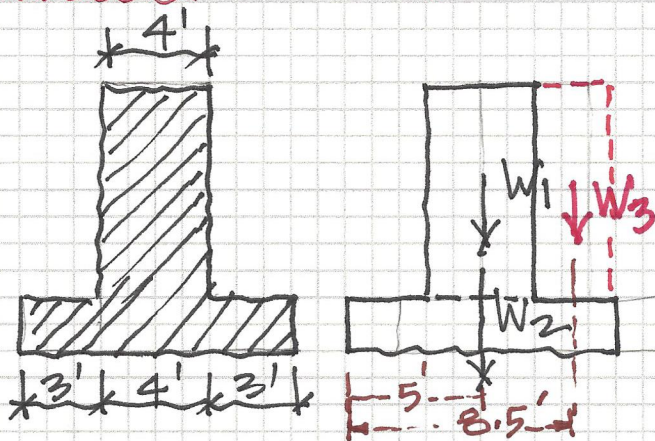
- (A) 1.9
- (B) 2.7
- (C) 3.0
- (D) 3.8

$$F.S. = ?$$



COMPLETE
SOLUTION

SOLUTION: (GRN-280)



$$\begin{aligned}\phi &= 30^\circ \\ \gamma_{\text{soil}} &= 108 \text{ pcf} \\ \gamma_{\text{con}} &= 145 \text{ pcf}\end{aligned}$$

$$H = \frac{1}{2} K_a \gamma_{\text{soil}} \cdot h^2$$

Rankine active soil pressure coeff: (K_a)

$$K_a = \frac{1 - \sin \phi}{1 + \sin \phi} = \frac{1 - \sin 30^\circ}{1 + \sin 30^\circ} = \frac{1}{3}$$

Total Lateral force: (H)

$$H = \frac{1}{2} K_a \gamma_{\text{soil}} \cdot h^2 = \frac{1}{2} \left(\frac{1}{3} \right) (108) (16^2) = 5832 \text{ lb}$$

Overturning moment: (M_{OT})

$$M_{OT} = H (\gamma^*) = (5832) (6 \text{ ft}) = 34,992 \text{ ft} \cdot \text{lb}$$

Vertical Loads: (W_i)

$$\text{Stem: } W_1 = (4') (16') (145) (1) = 9280 \text{ lb}$$

$$\text{Base: } W_2 = (2') (10') (145) (1) = 2900 \text{ lb}$$

$$\text{Soil: } W_3 = (3') (16') (108) (1) = 5184 \text{ lb}$$

Stabilizing moment: (M_s)

$$M_s = W_1 (x_1) + W_2 (x_2) + W_3 (x_3) = 9280 (5') + 2900 (5') + 5184 (8.5')$$

$$M_s = 104,964 \text{ ft} \cdot \text{lb}$$

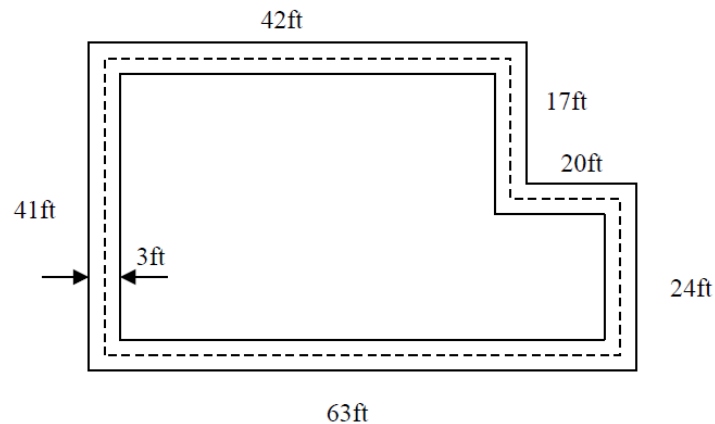
Factor of safety against overturning: (F.S.)

$$F.S. = M_s / M_{OT} = 104,964 / 34,992 = 3.0$$

AZ

CONSTRUCTION MANAGEMENT
PROFESSIONAL ENGINEERING (P.E.)
VOLUME COMPUTATIONS

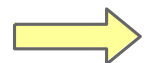
Problem-1



Swell factor of soil: 15%
Shrinkage of soil: 12%

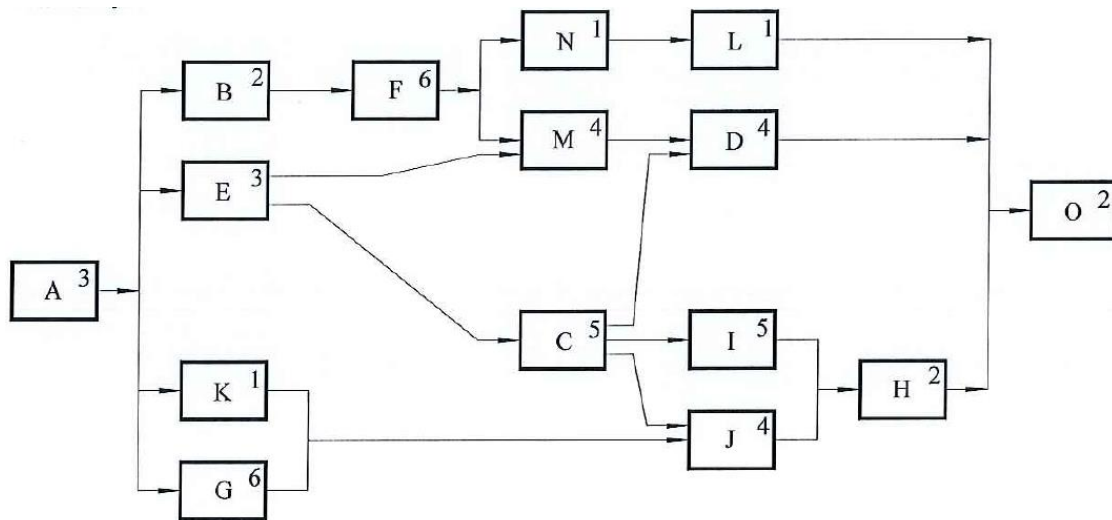
A contractor is excavating the trench shown above. His crew is supposed to dig the trench 5 ft deep \times 3 ft wide. The soil was tested to have an approximate swell factor of 15% and a shrinkage factor of 12%. The contractor is placing a 8" water pipe in the trench and then backfilling with the soil that was removed. The given dimensions are on centerlines. Does the contractor have enough soil to backfill the trench, or will his crew need more soil? If he needs more soil, how much (LCY-Loose Cubic Yards) is needed?

- (A) No need
- (B) 14.50
- (C) 12.34
- (D) 7.25



SOLUTION

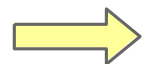
Problem-2



PDM Network Diagram

As an engineer responsible for the completion of a project on time and within budget you plan to keep track of the project activities using CPM. The PDM network diagram for the project is shown above. Each work item has a one-letter description and a duration in work days. The total float (in days) for work item "K" is most nearly?

- (A) 9 days
- (B) 6 days
- (C) 4 days
- (D) 0



Problem-3

	Machine A	Machine B
<i>Delivered Cost</i>	\$25,000	\$40,000
<i>Installation Expense</i>	\$5,000	\$10,000
<i>Estimated Life</i>	6 years	8 years
<i>Net Salvage Value</i>	0	\$10,000
<i>Annual Operating Costs</i>		
<i>Labor</i>	\$3,000	\$2,000
<i>Power</i>	\$2,000	\$1,750
<i>Repairs</i>	\$2,000	\$1,000
<i>Taxes</i>	\$450	\$750
<i>Interest Rate</i>	6%	6%

Assume you are required to decide which of two machines to purchase for a construction company. Both machines have been judged to be equally desirable in all matters except cost. Using the above listed data, answer the following question:

The total annual cost for machine A is most nearly:

- (A) \$11,850
- (B) \$12,540
- (C) \$13,552
- (D) \$14,560

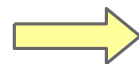


SOLUTION

Problem-4

Face brick laid in a running bond pattern (617 bricks per 100 sq. ft.) will be used for one wall of a single-story building. The length of the wall is 72 ft. and its height is 15'-2", both measured at the exterior face. The window and door openings are a total of 202 sq. ft. Assuming a %5 waste, the total number of face bricks required is most nearly:

- (A) 5,491
- (B) 5,766
- (C) 7,075
- (D) 7,428



SOLUTION

SOLUTIONS:

Solution: #1

SOLUTIONS BY
DR. ZEINAB
FARAHMANDFAR

Step 1: Find length of trench

$$42ft + 17ft + 20ft + 24ft + 63ft + 41ft = 207ft$$

Step 2: Find the Volume of the soil in the trench

$$5ft \times 3ft \times 207ft = 3105 ft^3$$

Step 3: Find the Volume after compaction

$$(3105 ft^3)(1 - 0.12) = (3105 ft^3)(0.88) = 2732.4 ft^3$$

Step 4: Find the Volume of the soil needed as: Volume of Trench –

Volume of Pipe

$$3105 ft^3 - \pi(d^2/4)(207ft) = \pi((8/12)^2/4)(207ft)$$

$$3105 ft^3 - 72.25 ft^3 = 3032.75 ft^3$$

Step 5: Find out if more soil is needed

Volume of compacted soil needed – Volume of compacted soil available

$$3032.75 ft^3 - 2732.4 ft^3 = 300.35 ft^3$$

→ So the KTR (Contractor) needs to bring in more soil

Step 6: How much soil does the contractor needs to bring in?

$$\frac{\text{Volume of compacted soil}}{(1 - \text{Shrinkage factor})} = BCF_{(\text{Bank Cubic feet})}$$

$$\frac{300.35}{0.88} = 341 BCF$$

$$LCF_{(\text{Loose Cubic feet})} = BCF \times 1.15 = 392 / 27 = 14.5 LCY$$

The answer is (B)

Solution: #2

Do the forward pass and backward pass computations to find the longest path through the network. The results are summarized in the below table:

WI	Dur.	ES (Early Start)	EF (Early Finish)	LS (Late Start)	LF (Late Finish)
A	3	0	3	0	3
B	2	3	5	3	5
E	3	3	6	4	7
K	1	3	4	12	13
G	6	3	9	7	13
F	6	5	11	5	11
N	1	11	12	17	18
M	4	11	15	11	15
C	5	6	11	7	12
L	1	12	13	18	19
D	4	15	19	15	19
I	5	11	16	12	17
J	4	11	15	13	17
H	2	16	18	17	19
O	2	19	21	19	21

The EF for WI “K” is day 4. The latest that WI “J”, the immediate successor to WI “K” can start is day 13. Thus, the total float for WI “K” is:

$$TF_K = TF_J - EF_K = 13 - 4 = 9 \text{ days}$$

or

$$TF_K = LS_K - ES_K = 13 - 4 = 9 \text{ days}$$

The answer is (A)

Solution: #3

$$AC = P(A/P, 6\%, 6yrs) + AE - L(A/F, 6\%, 6yrs)$$

$$AC = (25,000 + 5,000)(0.2034) + (3,000 + 2,000 + 2,000 + 450) - 0$$

$$AC = \$13,552$$

The answer is (C)

Solution: #4

Find the gross wall area:

$$A_g = Lh = (72ft)(15' - 12") = (72ft)(15.167ft) = 1,092 \text{ sq. ft}$$

Next find the net wall area:

$$A_n = A_g - \text{Opennings} = 1,092 - 202 = 890 \text{ sq. ft}$$

Then:

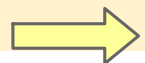
$$N_{req} = A_n \left(\frac{617 \text{ bricks}}{100 \text{ sq. ft}} \right) \left(1 + \frac{\% \text{ waste}}{100\%} \right) = 890 \left(\frac{617}{100} \right) \left(1 + \frac{5\%}{100\%} \right) = 5,766 \text{ bricks}$$

The answer is (B)

FUNDAMENTALS OF ENGINEERING (F.E.)
PROFESSIONAL ENGINEERING (P.E.)
GEOTECHNICAL ENGINEERING
PERMEABILITY

PREPARED BY
DR. LEI WANG

- (1) A permeability test is conducted with a sample of soil that is 50 mm in diameter and 100 mm long. The head is kept constant at 200 mm. The flow is 1.5 mL in 8 min. The coefficient of permeability (**m/min**) is most nearly:
- (A) 4.2×10^{-5}
 - (B) 4.8×10^{-5}
 - (C) 5.4×10^{-5}
 - (D) 6.0×10^{-5}
- (2) A permeability test is conducted with a sample of soil that is 60 mm in diameter and 120 mm long. The head is kept constant at 250 mm. The flow is 2 mL in 10 min. The coefficient of permeability (**m/min**) is most nearly:
- (A) 2.6×10^{-5}
 - (B) 3.0×10^{-5}
 - (C) 3.4×10^{-5}
 - (D) 3.8×10^{-5}
- (3) A certain varved clay consists of alternating horizontal layers of silt and clay. The silt layers are 10 mm thick and have $k = 2 \times 10^{-4}$ cm/s; the clay layers are 20 mm thick and have $k = 8 \times 10^{-7}$ cm/s. The value for the equivalent horizontal hydraulic conductivity (**cm/s**) for these two layers is most nearly:
- (A) 6.7×10^{-4}
 - (B) 6.7×10^{-5}
 - (C) 6.7×10^{-6}
 - (D) 6.7×10^{-7}



- (4) A certain varved clay consists of alternating horizontal layers of silt and clay. The silt layers are 10 mm thick and have $k = 2 \times 10^{-4}$ cm/s; the clay layers are 20 mm thick and have $k = 8 \times 10^{-7}$ cm/s. What is the closest value for the equivalent vertical hydraulic conductivity (cm/s) for these two layers is most nearly:

- (A) 1.2×10^{-4}
- (B) 1.2×10^{-5}
- (C) 1.2×10^{-6}
- (D) 1.2×10^{-7}



SOLUTIONS

SOLUTIONS
BY
DR. LEI WANG

Solution: #1

Using NCEES-Ref. Handbook, v.9.4, formulas on page 146

$$k = Q/iAt, \quad i = dh/dL, \quad \text{Thus, } k = QL/hAt$$

$$k = \frac{QL}{hAt} = \frac{1.5 \times 100}{200 \times (\pi \frac{50^2}{4}) \times (8)} = 4.8 \times 10^{-5} m/min$$

The answer is (B)

Solution: #2

$$k = \frac{QL}{hAt} = \frac{2 \times 120}{250 \times (\pi \frac{60^2}{4}) \times (10)} = 3.4 \times 10^{-5} m/min$$

The answer is (C)

Solution: #3

$$k_x = \frac{\sum k_i H_i}{\sum H_i} = \frac{(2 \times 10^{-4}) \times (10) + (8 \times 10^{-7}) \times (20)}{(10 + 20)} = 6.7 \times 10^{-5} cm/s$$

The answer is (B)

Solution: #4

$$k_z = \frac{\sum H_i}{\sum (\frac{H_i}{k_i})} = \frac{10 + 20}{\frac{10}{2 \times 10^{-4}} + \frac{20}{8 \times 10^{-7}}} = 1.2 \times 10^{-6} cm/s$$

The answer is (C)

FUNDAMENTALS OF ENGINEERING
TRANSPORTATION ENGINEERING
TRAFFIC SAFETY

PREPARED BY
DR. BRYAN HIGGS

Problem 1

The crash rate per hundred million vehicle miles for a 0.75 mile section of highway with 8 crashes over 3 years and an ADT of 12,000 is most nearly:

- (A) 73.1
- (B) 81.2
- (C) 89.3
- (D) 97.4

Problem 2

The crash rate per million entering vehicles for an intersection between a roadway with an ADT of 12,000 and a roadway with an ADT of 3,000 that experienced 12 crashes in one year is most nearly:

- (A) 2.2
- (B) 5.5
- (C) 13.7
- (D) 23.2

Problem 3

Rumble strips, guardrail, and wide shoulders are being added to a section of roadway with an ADT of 13,000 and a crash history of 6 crashes per year. Rumble strips have a crash reduction factor of 0.33. Guardrail has a crash reduction factor of 0.58. Wide shoulders have a crash reduction factor of 0.36. The number of crashes prevented on the roadway, after all crash countermeasures have been installed and the ADT has increased by 2,500 vehicles, is most nearly:

- (A) 3
- (B) 4
- (C) 5
- (D) 6



COMPLETE
SOLUTION

Problem 4

Rumble strips, guardrail, and wide shoulders are being added to a 0.5 mile section of roadway with an ADT of 25,000 and a crash rate of 65 per hundred million vehicle miles. Rumble strips have a crash reduction factor of 0.33. Guardrail has a crash reduction factor of 0.58. Wide shoulders have a crash reduction factor of 0.36. The number of crashes prevented on the roadway, after all crash countermeasures have been installed and the ADT has increased by 8,000 vehicles, is most nearly:

- (A) 3
- (B) 4
- (C) 5
- (D) 6



FUNDAMENTALS OF ENGINEERING
TRANSPORTATION ENGINEERING
SOLUTIONS

SOLUTIONS BY
DR. BRYAN HIGGS

Solution# 1

The crash rate per hundred million vehicle miles for a 0.75 mile section of highway with 8 crashes over 3 years and an ADT of 12,000 is most nearly:

Using the formulas from NCEES FE Handbook, page 172

$$RMVM = \frac{A \times 100,000,000}{VMT}$$

$$RMVM = \frac{8 \times 100,000,000}{(12,000)(3 * 365)(0.75)} = 81.2$$

<i>RMVM</i> :	crash rate per hundred million vehicle miles
<i>A</i> :	number of crashes during a given period
<i>VMT</i> :	vehicle miles of travel during the given period (ADT x number of days x length of road)
<i>ADT</i> :	average daily traffic on the roadway segment

Thus, the answer is: (B)

Solution # 2

The crash rate per million entering vehicles for an intersection between a roadway with an ADT of 12,000 and a roadway with an ADT of 3,000 that experienced 12 crashes in one year is most nearly:

Using the formulas from NCEES FE Ref. Handbook, Page 172

$$RMEV = \frac{A \times 1,000,000}{V}$$

$$RMEV = \frac{12 \times 1,000,000}{(12,000 + 3,000)(365)} = 2.2$$

<i>RMEV</i> :	crash rate per million entering vehicle
<i>A</i> :	number of crashes occurring in a single year
<i>V</i> :	(ADT x 365)
<i>ADT</i> :	average daily traffic entering intersection

Thus, the answer is: (A)

Solution # 3

Rumble strips, guardrail, and wide shoulders are being added to a section of roadway with an ADT of 13,000 and a crash history of 6 crashes per year. Rumble strips have a crash reduction factor of 0.33. Guardrail has a crash reduction factor of 0.58. Wide shoulders have a crash reduction factor of 0.36. The number of crashes prevented on the roadway, after all crash countermeasures have been installed and the ADT has increased by 2,500 vehicles, is most nearly:

Using the formulas from NCEES FE Ref. Handbook, Page 172

$$\text{crashes prevented} = N \times CR \frac{ADT_{After}}{ADT_{Before}}$$

Where:

N – expected number of crashes if countermeasure is not implemented and if the traffic volume remains the same

$CR = CR_1 + (1 - CR_1) CR_2 + (1 - CR_1)(1 - CR_2) CR_3 + \dots + (1 - CR_1)\dots(1 - CR_{m-1}) CR_m$

CR_i – crash reduction factor for countermeasure i

m – number of countermeasures at the site

$$\begin{aligned}\text{crashes prevented} &= 6 \\ &\times [0.33 + (1 - 0.33)0.58 \\ &+ (1 - 0.33)(1 - 0.58)0.36] \frac{(13,000 + 2,500)}{13,000} \\ &= 5.9\end{aligned}$$

Thus, the answer is: (D)

Solution #4

Using the formulas from NCEES FE Ref. Handbook, Page 172

$$\text{crashes prevented} = N \times CR \frac{ADT_{After}}{ADT_{Before}}$$

$$RMVM = \frac{A \times 100,000,000}{VMT}$$

Where:

N – expected number of crashes if countermeasure is not implemented and if the traffic volume remains the same

$CR = CR_1 + (1 - CR_1) CR_2 + (1 - CR_1)(1 - CR_2) CR_3 + \dots + (1 - CR_1)\dots(1 - CR_{m-1}) CR_m$

CR_i – crash reduction factor for countermeasure i

m – number of countermeasures at the site

$RMVM$ – crash rate per hundred million vehicle miles

A – number of crashes during a given period

VMT – vehicle miles of travel during the given period ($ADT \times \text{number of days} \times \text{length of road}$)

ADT - average daily traffic on the roadway segment

Solution

$$65 = \frac{A \times 100,000,000}{(25,000)(365 * 1)(0.5)}$$

$$A = \frac{65(25,000)(365 * 1)(0.5)}{100,000,000} = 2.965$$

$$\begin{aligned}
 &\text{crashes prevented} \\
 &= 2.965 \\
 &\times [0.33 + (1 - 0.33)0.58 \\
 &+ (1 - 0.33)(1 - 0.58)0.36] \frac{(25,000 + 8,000)}{25,000} \\
 &= 3.2
 \end{aligned}$$

Thus, the answer is: (A)



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Career Highlights:

- 1- Ph.D. in civil engineering/construction management from Clemson University
- 2- *Developed Courses* for University of Maryland
- 3- *Adjunct Faculty* at University of Maryland
- 4- *Adjunct Faculty* at George Mason University
- 5- Published 12 papers in peer-reviewed journals and conferences
- 6- *Technical Engineer*, Savand Geotechnical Engineering Service Company, Iran
- 7- *Project Coordinator*, Iran Broadcasting, Iran
- 8- *Member*, American Society of Civil Engineers (ASCE)
- 9- *Member*, North American Society for Trenchless Technology (NASTT)
- 10- *Scholarly Article Reviewer*, Several International Journals
- 11- *Participation in fund*, Submitted to NIST entitled “Resilience-Based Water Infrastructure Rehabilitation Planning in a Multi-Hazard Context”
- 12- *Research Assistant*, Clemson University, developed a decision architecture to enhance the resilience of water infrastructure networks that can be evaluated based on the performance of the system under multi-hazard condition.
- 13- *Research Assistant*, KNT University, developed an optimization model using Honey Bees Mating Optimization (HBMO) algorithm to find an optimal operational strategy of multi-reservoir systems.