ASCE NATIONAL CAPITAL SECTION eNewsletter
National Capital Section
FOUNDED 1916

JANUARY 2016

DR. Z's CORNER

Conquering the FE & PE exams
Examples & Applications

Topics covered in this month's column:

- **FE CIVIL Exam Topics & Number of Questions**
- **ASCE-7-10 Minimum Design Loads**
- **Factored Loads and Factored Moments**
- **Matrix Computations, Inverse Matrix**
- **Pulley and Cable Systems**
- **Centroids & Moments of Inertia**
- **Concurrent Force Systems**
- **Combined Stress Problems (*N*+*M*)**
- **Volume Computations, Borrow Pits**
- **Determinate Plane Truss Analysis**
- **Reinforced Concrete Beam,**
- **Open Web Steel Joist (OWSJ) Computations**

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 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)**

* Here the number of questions are the average values taken from the NCEES Reference Handbook (Version 9.1 / Computer-Based Test)

MINIMUM DESIGN LOADS
FOR BUILDINGS AND OTHER STRUCTURES

AMERICAN SOCIETY OF CIVIL ENGINEERS

ASCE / SEI 7-10

MINIMUM DESIGN LOADS FOR BUILDINGS AND OTHER STRUCTURES (7-10, THIRD PRINTING)

American Society of Civil Engineers
Standards ASCE/SEI 7-10
2013 / 636 pp.

(1) $U = 1.4\,(D + F)$

(2) $U = 1.2\,(D + F + T) + 1.6\,(L + H) + 0.5\,(L_r \text{ or } S \text{ or } R)$

(3) $U = 1.2\,D + 1.6\,(L_r \text{ or } S \text{ or } R) + (1.0\,L \text{ or } 0.8\,W)$

(4) $U = 1.2\,D + 1.6\,W + 1.0\,L + 0.5\,(L_r \text{ or } S \text{ or } R)$

(5) $U = 1.2\,D + 1.0\,E + 1.0\,L + 0.2\,S$

(6) $U = 0.9\,D + 1.6\,W + 1.6\,H$

(7) $U = 0.9\,D + 1.0\,E + 1.6\,H$

U = design or ultimate load (kips)
D = dead load (kips)
L = live load (kips)
F = loads due thefluids weight
T = loads due to temperature
H = loads due to earth pressure
L_r = roof live load
S = snow load
R = rain load
W = wind load
E = earthquake or seismic load

$U = 1.2\,D + 1.6\,L$
D = DEAD LOAD
L = LIVE LOAD

Problem: (R/C Column, Load Combinations)

A R/C building column is subjected to the following loads:

> Dead Load : D = 115 kip
> Live Load : L = 60 kip
> Wind Load : W = 70 kip (compression)
> Wind Load : W = 105 kip (tension)

Determine the required design strength of this column.

Solution:

(1) $U = 1.4\,(D + F)$ = 1.4 (115+0) = 161 kips

(2) $U = 1.2\,(D + F + T) + 1.6\,(L + H) + 0.5\,(L_r \text{ or } S \text{ or } R)$

P_u = 1.2 (115) + 1.6 (60) = 234 kips

(3) $U = 1.2\,D + 1.6\,(L_r \text{ or } S \text{ or } R) + (1.0\,L \text{ or } 0.8\,W)$

= 1.2 (115) + 1.0 (60) = 198 kips

= 1.2 (115) + 0.8 (70) = 194 kips

= 1.2 (115) + 0.8 (-105) = 54 kips

(4) $U = 1.2\,D + 1.6\,W + 1.0\,L + 0.5\,(L_r \text{ or } S \text{ or } R)$

= 1.2 (115) + 1.6 (70) + 1.0 (60) = 310 kips

= 1.2 (115) + 1.6 (-90) + 1.0 (60) = 30 kips

(5) $U = 1.2\,D + 1.0\,E + 1.0\,L + 0.2\,S$

= 1.2 (110) + 1.0 (0) + 1.0 (60) + 0.2 (0) = 198 kips

(6) $U = 0.9\,D + 1.6\,W + 1.6\,H$

= 0.9 (115) + 1.6 (70) + 1.6 (0) = 216 kips

= 0.9 (115) + 1.6 (-105) + 1.6 (0) = - 65 kips (uplift)

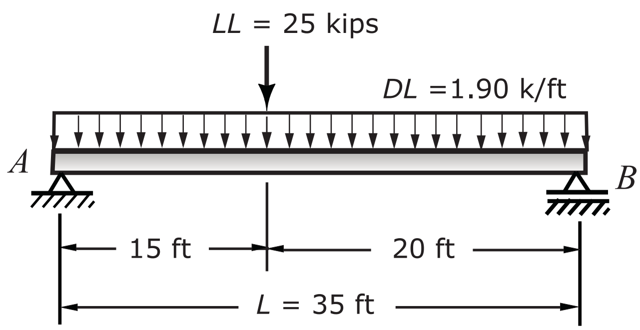
(7) $U = 0.9\,D + 1.0\,E + 1.6\,H$ = 0.9 (115) = 104 kips

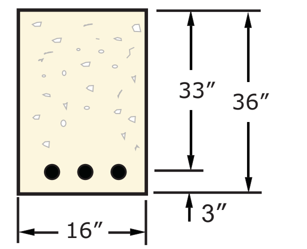
Answer:
P_u = 310 kip (compression)
P_u = 65 kip (tension)

STRUCTURES / REINFORCED CONCRETE

FACTORED LOADS / MAX. FACTORED MOMENT

Service Loads

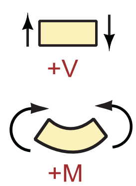




$\gamma_{R/C} = 150\ \text{lb/ft}^3$

The beam weight will be included in the computations:

A simply supported R/C beam is loaded as shown. Considering the weight of the concrete beam, the maximum *factored* bending moment (k-ft) is most nearly:



(A) 520
(B) 593
(C) 686
(D) 793

$M_u = ?$

COMPLETE SOLUTION

MCBM-325
ZEYTINCI
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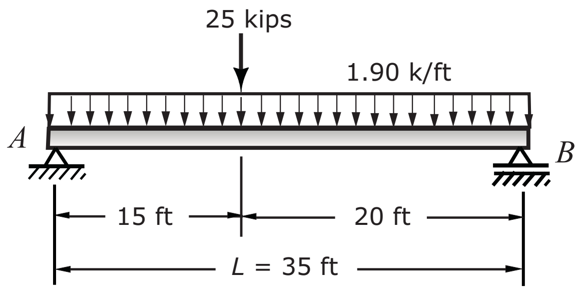
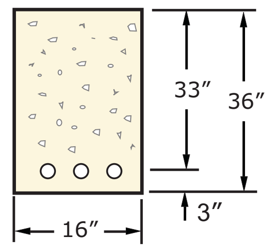
FACTORED LOADS / FACTORED MOMENTS

Service Loads

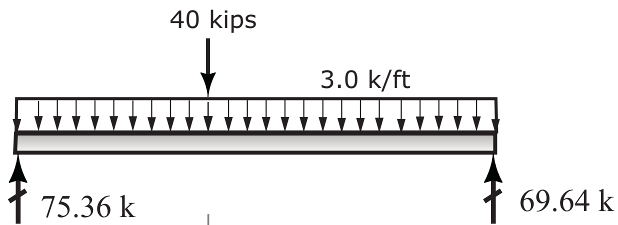




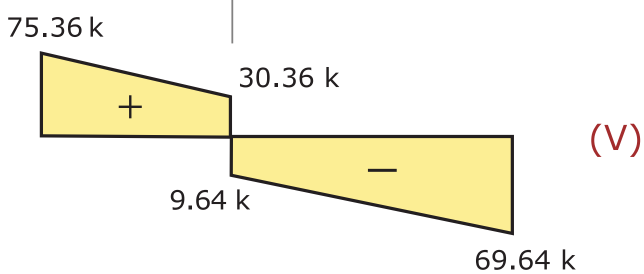
Section

$\gamma_{R/C}$ = 150 lb/ft^3

Factored Loads



Shear Diagram



Beam Weight

$$BM = \frac{(16)(36)}{144}\ (150) = 600 \text{ lb/ft} = 0.6$$

Factored Dead Load

$$w_u\ = 1.2\ (0.6 + 1.9) = 1.2\ (2.5) = 3.0 \text{ k/ft}$$

Factored Live Load

$$w_u\ = 1.6\ (25 \text{ kips}) = 40 \text{ kips}$$

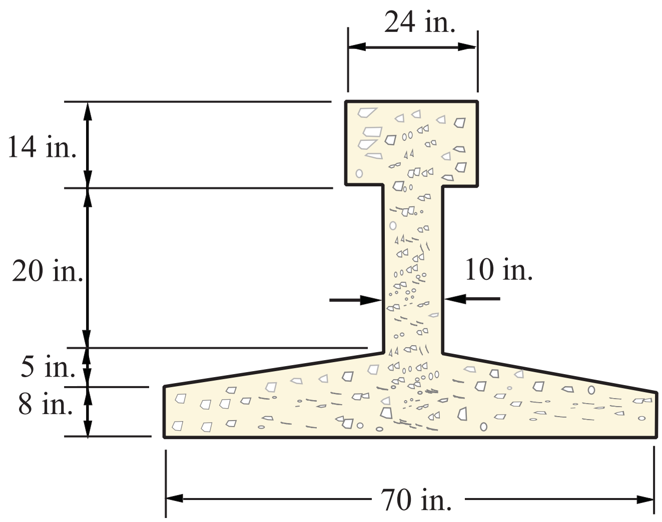
Maximum Factored Moment

$$M_u\ = 0.5\ (15)\ (75.36 + 30.36) = 792.9 \text{ ft-kips}$$

$$\boxed{M_u = 792.9 \text{ ft-kips}}$$

STRUCTURAL ANALYSIS

LOAD ANALYSIS



FE/PE EXAM

Unit Weight:

γ_c = 125 lb/ft^3

The dimensions of a light weight reinforced concrete beam section is given as shown in the figure. Using the listed data, answer the following questions:

(1) The cross-sectional area (ft^2) is most nearly:

(A) 12.5
(B) 10.5
(C) 9.0
(D) 6.0

(2) The uniform dead load (lb/ft) is most nearly:

(A) 750
(B) 825
(C) 985
(D) 1125

LOAD-250-A
LOADS
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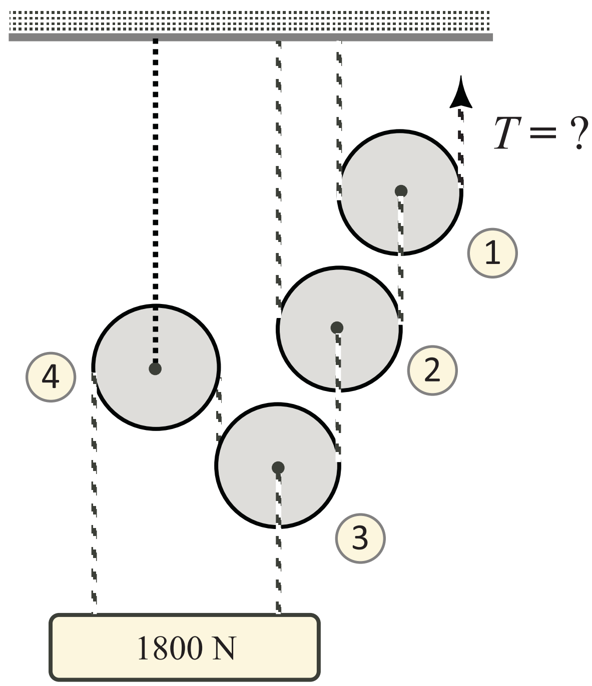
FUNDAMENTALS OF ENGINEERING

PULLEY SYSTEMS



Four pulley system is used to lift 1800 Newton load as shown in the figure. Knowing that the pulleys are frictionless and weightless, the tension *T* applied (Newtons) to pulley # 1 is most nearly:

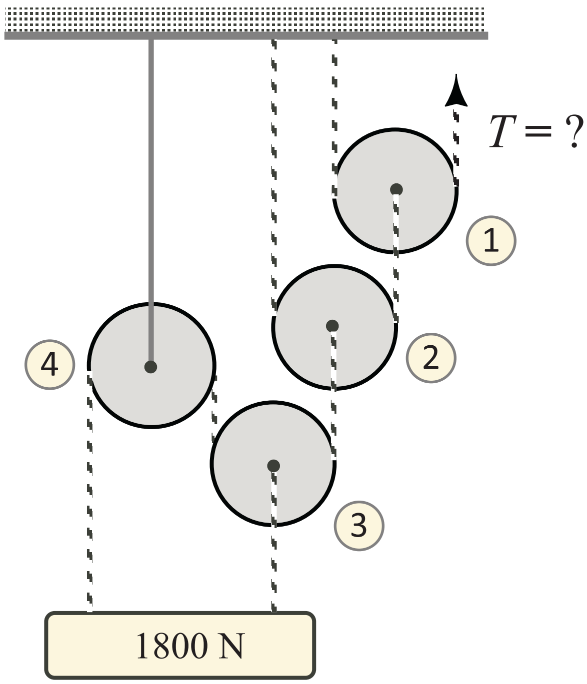
(A) 100
(B) 150
(C) 200
(D) 225

$T = ?$

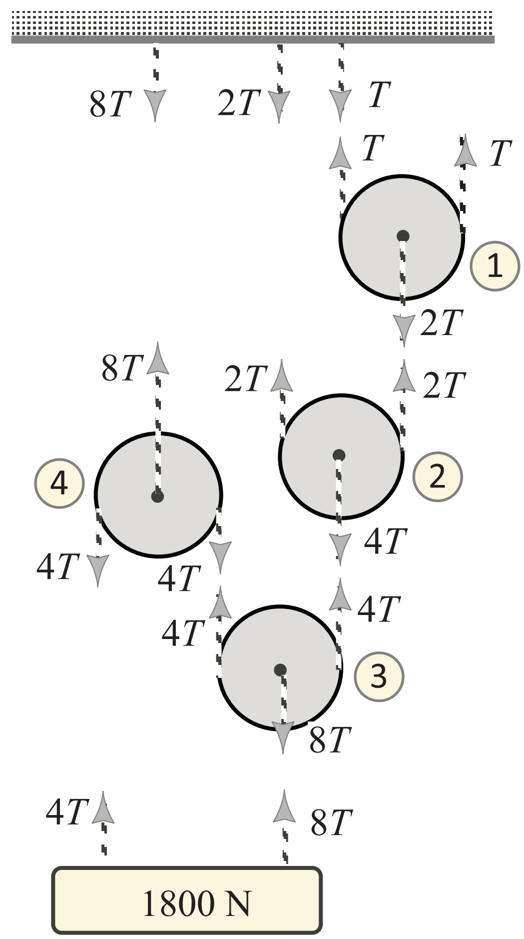
COMPLETE SOLUTION

FUNDAMENTALS OF ENGINEERING

PULLEY SYSTEMS



PULLEYS ARE WEIGHTLESS
AND FRICTIONLESS



(FBD)

Writing the equilibrium equation in vertical direction:

$$\uparrow \Sigma F_y = 0 \longrightarrow 4T + 8\,T = 1800$$

$$\boxed{T = 150 \text{ N}}$$

PLLY-120-ANS
ZEYTINCI
SPRING 2015

FUNDAMENTALS OF ENGINEERING

MATRIX COMPUTATIONS

Problem

$$A = \begin{bmatrix} 3 & -3 & 2 \\ 2 & 5 & -3 \\ 3 & -1 & 1 \end{bmatrix}$$

For the matrix A is given above, answer the following questions:

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

(A) 4
(B) 5
(C) 6
(D) 8

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

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

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

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

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

Example: (Inverse Matrix)

$$A = \begin{bmatrix} 3 & -3 & 2 \\ 2 & 5 & -3 \\ 3 & -1 & 1 \end{bmatrix}$$

(a) Find the cofactor matrix
(b) Find the adjoint matrix
(c) Find the inverse matrix

Solution:

$$cof\,A = \begin{bmatrix} +\begin{vmatrix} 5 & -3 \\ -1 & 1 \end{vmatrix} & -\begin{vmatrix} 2 & -3 \\ 3 & 1 \end{vmatrix} & +\begin{vmatrix} 2 & 5 \\ 3 & -1 \end{vmatrix} \\ -\begin{vmatrix} -3 & 2 \\ -1 & 1 \end{vmatrix} & +\begin{vmatrix} 3 & 2 \\ 3 & 1 \end{vmatrix} & -\begin{vmatrix} 3 & -3 \\ 3 & -1 \end{vmatrix} \\ +\begin{vmatrix} -3 & 2 \\ 5 & -3 \end{vmatrix} & -\begin{vmatrix} 3 & 2 \\ 2 & -3 \end{vmatrix} & +\begin{vmatrix} 3 & -3 \\ 2 & 5 \end{vmatrix} \end{bmatrix} = \begin{bmatrix} 2 & -11 & -17 \\ 1 & -3 & -6 \\ -1 & 13 & 21 \end{bmatrix}$$

$$adj\,A = \begin{bmatrix} 2 & -11 & -17 \\ 1 & -3 & -6 \\ -1 & 13 & 21 \end{bmatrix}^T = \begin{bmatrix} 2 & 1 & -1 \\ -11 & -3 & 13 \\ -17 & -6 & 21 \end{bmatrix}$$

Determinant of the square matrix, det $A = |A| = 5$

$$A^{-1} = \frac{adj\,A}{|A|} = \begin{bmatrix} \frac{2}{5} & \frac{1}{5} & \frac{-1}{5} \\ \frac{-11}{5} & \frac{-3}{5} & \frac{13}{5} \\ \frac{-17}{5} & \frac{-6}{5} & \frac{21}{5} \end{bmatrix}$$

Check

$$A\,A^{-1} = \begin{bmatrix} 3 & -3 & 2 \\ 2 & 5 & -3 \\ 3 & -1 & 1 \end{bmatrix} \begin{bmatrix} \frac{2}{5} & \frac{1}{5} & \frac{-1}{5} \\ \frac{-11}{5} & \frac{-3}{5} & \frac{13}{5} \\ \frac{-17}{5} & \frac{-6}{5} & \frac{21}{5} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

O.K. ✔

THE ADJOINT MATRIX (adj A)

Previously we have defined the minors and cofactors. The adjoint matrix, designated by adj A, of a square matrix A is the transpose of cof A.

$$\boxed{adj\ A = (cof\ A)^T}$$

Example

$$A = \begin{bmatrix} -2 & 3 & 5 \\ 4 & 7 & -2 \\ 5 & -2 & -9 \end{bmatrix}$$

(a) Find the cofactor matrix
(b) Find the adjoint matrix
(c) Find the inverse matrix

$$cof\ A = \begin{bmatrix} +\begin{vmatrix} 7 & -2 \\ -2 & -9 \end{vmatrix} & -\begin{vmatrix} 4 & -2 \\ 5 & -9 \end{vmatrix} & +\begin{vmatrix} 4 & 7 \\ 5 & -2 \end{vmatrix} \\ -\begin{vmatrix} 3 & 5 \\ -2 & -9 \end{vmatrix} & +\begin{vmatrix} -2 & 5 \\ 5 & -9 \end{vmatrix} & -\begin{vmatrix} -2 & 3 \\ 5 & -2 \end{vmatrix} \\ +\begin{vmatrix} 3 & 5 \\ 7 & -2 \end{vmatrix} & -\begin{vmatrix} -2 & 5 \\ 4 & -2 \end{vmatrix} & +\begin{vmatrix} -2 & 3 \\ 4 & 7 \end{vmatrix} \end{bmatrix} = \begin{bmatrix} -67 & 26 & -43 \\ 17 & -7 & 11 \\ -41 & 16 & -26 \end{bmatrix}$$

$$adj\ A = \begin{bmatrix} -67 & 26 & -43 \\ 17 & -7 & 11 \\ -41 & 16 & -26 \end{bmatrix}^T = \begin{bmatrix} -67 & 17 & -41 \\ 26 & -7 & 16 \\ -43 & 11 & -26 \end{bmatrix}$$

Determinant of this square matrix, det A = $|A|$ = - 3

$$\boxed{A^{-1} = \frac{adj\ A}{|A|}}$$

$$A^{-1} = \begin{bmatrix} \frac{67}{3} & \frac{-17}{3} & \frac{41}{3} \\ \frac{-26}{3} & \frac{7}{3} & \frac{-16}{3} \\ \frac{43}{3} & \frac{-11}{3} & \frac{26}{3} \end{bmatrix}$$

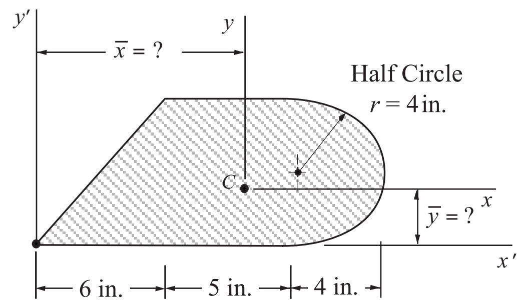
Check and see if

$$\boxed{A \cdot A^{-1} = I}$$

STATICS / MECHANICS OF SOLIDS

CENTROIDS & MOMENTS OF INERTIA

Problem



FE-PE EXAM

The dimensions of a composite area is given as shown. Using the given data, answer the following questions:

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

(A) 6.25
(B) 5.50
(C) 4.85
(D) 3.64

$\bar{y} = ?$

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

(A) 6.25
(B) 7.50
(C) 8.47
(D) 9.64

$\bar{x} = ?$

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

(A) 430
(B) 532
(C) 618
(D) 630

$I_{cx} = ?$

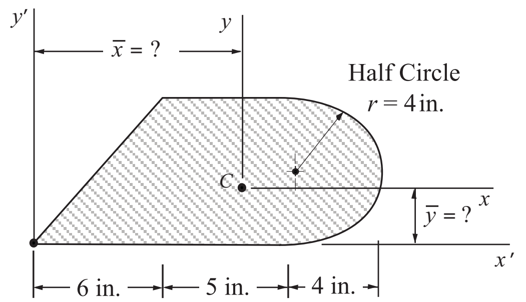
(4) the moment of inertia (in^4) about the *vertical* centroidal axis is most nearly

(A) 2280
(B) 1980
(C) 1090
(D) 1210

$I_{cy} = ?$

COMPLETE SOLUTION

Centroid / Moments of Inertia



Centroid Calculations ($\bar{x}$)

	A_i	x_i	$A_i\,x_i$
	in.^{2}	in.	in.^{3}
1	24.0	4.00	96.00
2	40.0	8.50	340.00
3	25.13	12.7	319.15
Σ	**89.13**	—	**755.15**

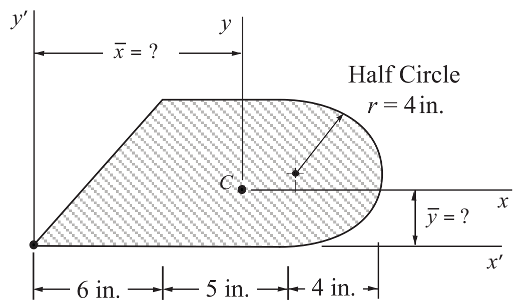
$$\bar{x} = \frac{\Sigma A_i\, x_i}{\Sigma A_i} = \frac{755.15}{89.13} = 8.47 \text{ in.}$$

Centroid Calculations ($\bar{y}$)

	A_i	y_i	$A_i\,y_i$
	in.^{2}	in.	in.^{3}
1	24.0	2.67	64.08
2	40.0	4.00	160.00
3	25.13	4.00	100.52
Σ	**89.13**	—	**324.60**

$$\bar{y} = \frac{\Sigma A_i\, y_i}{\Sigma A_i} = \frac{324.60}{89.13} = 3.64 \text{ in.}$$

Centroid / Moments of Inertia



Moment of Inertia Calculations (Ix)

	I_o	A_i	d_i	$A_i d_i^2$
	in.^{4}	in.^{2}	in.	in.^{4}
1	85.33	24.00	0.97	22.58
2	213.33	40.00	0.36	5.18
3	100.537	25.13	0.36	3.26
Σ	399.19		—	31.02

$$I_{cx} = \Sigma I_o + \Sigma A_i \,.\, d_i^{\,2} = 399.19 + 31.02 = 430.21 \text{ in.}^4$$

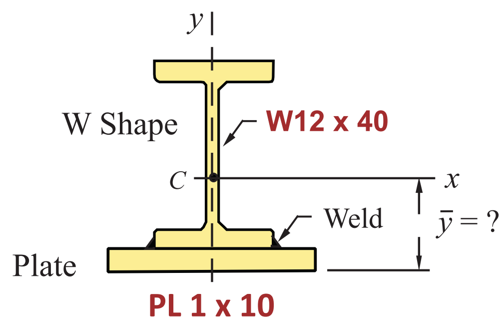
Moment of Inertia Calculations (I_{cy})

	I_o	A_i	d_i	$A_i d_i^2$
	in.^{4}	in.^{2}	in.	in.^{4}
1	48.00	24.00	4.47	479.5
2	83.33	40.00	0.03	0.036
3	28.11	25.13	4.23	449.6
Σ	159.45		—	929.2

$$I_{cy} = \Sigma I_o + \Sigma A_i \,.\, d_i^{\,2} = 159.4 + 929.2 = 1088.6 \text{ in.}^4$$

STATICS / MECHANICS OF SOLIDS

CENTROIDS & MOMENTS OF INERTIA



FE-PE EXAM

A W 12 x 40 section and a plate are welded together to form a composite section as shown. Using the listed data answer the following questions:

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

(A) 6.0
(B) 5.5
(C) 4.6
(D) 4.0

$\bar{y} = ?$

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

(A) 429
(B) 532
(C) 618
(D) 630

$I_{cx} = ?$

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

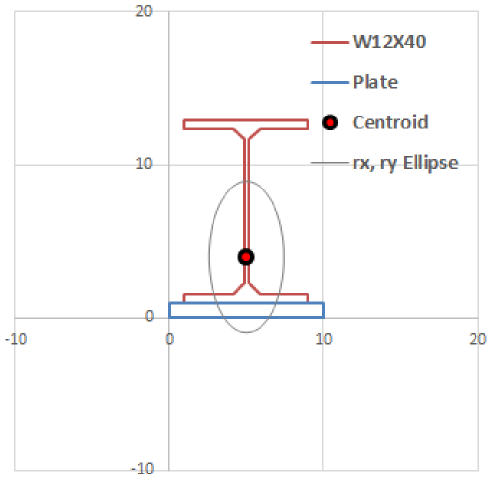
(A) 228.4
(B) 132.5
(C) 127.5
(D) 110.6

$I_{cy} = ?$

COMPLETE SOLUTION

MCC-676
ZEYTINCI
FALL 2014

Solution:



TOP W-SHAPE (1)	W12X40			
ID	**Quantity**	**Symbol**	**Value**	**Unit**
4	Area	A	11.70	in^2
5	Depth	d	11.90	in
37	x - Moment of Inertia	I_x	307.00	in^4
41	y - Moment of Inertia	I_y	44.10	in^4

BOTTOM - PLATE (2)	
Plate Width (in.)	10
Plate Thickness (in.)	1

ID	Quantity	Symbol	Value	Unit
4	Area	A	10.00	in^2
37	x - Moment of Inertia	I_x	0.83	in^4
41	y - Moment of Inertia	I_y	83.33	in^4

	A_i (in^2)	y_i (in)	A_iy_i (in^3)
1	11.70	6.95	81.32
2	10.00	0.50	5.00
Σ	**21.70**		**86.32**

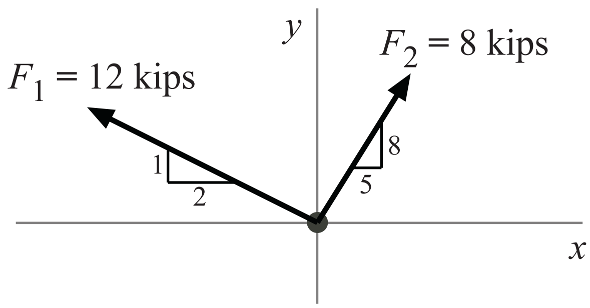
	I_0 (in^4)	A_i (in^2)	d_i (in)	$A_id_i^2$ (in^4)
1	307.00	11.70	2.97	103.37
2	0.83	10.00	3.48	120.94
Σ	**307.83**			**224.31**

COMPOSITE SECTION PROPERTIES				
Area	A =	21.70	in^2	
Centroid - y	y_{bar} =	**3.98**	in	(from bottom)
x - Moment of Inertia	I_x =	**532.14**	in^4	
y - Moment of Inertia	I_y =	**127.43**	in^4	
Total depth	d =	12.90	in	
x - Radius of Gyration	r_x =	4.95	in	
y - Radius of Gyration	r_y =	2.42	in	

STATICS

CONCURRENT FORCES

Problem:



Two forces act as shown in the figure. Using the listed data answer the following:

(1) The magnitude (kips) of the resultant of the two forces is most nearly:

(A) 20.0
(B) 12.6
(C) 13.8
(D) 15.6

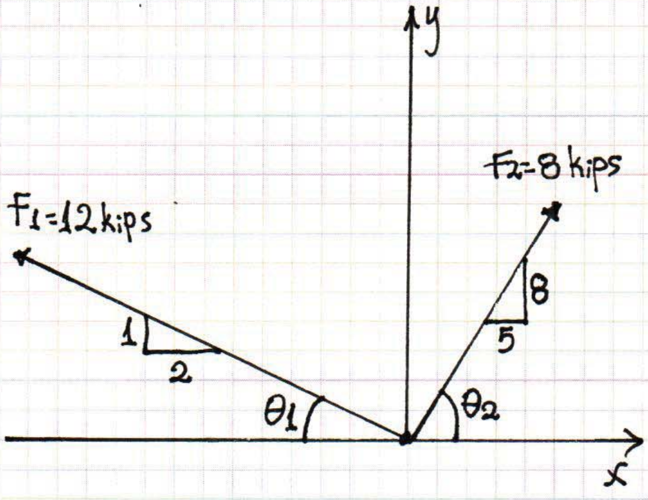
(2) The angle (degrees) of the resultant from the x axis is most nearly:

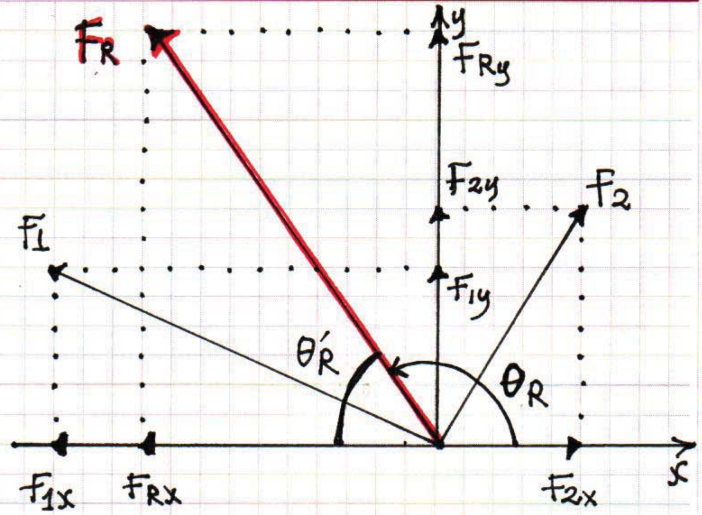
(A) 44
(B) 118
(C) 86
(D) 132

(3) The vector form (kips) of the resultant is most nearly:

(A) - 6.5 **i** + 12.1 **j**
(B) 12.1 **i** - 6.5 **j**
(C) - 8.2 **i** + 14.5 **j**
(D) 8.2 **i** - 14.5 **j**

COMPLETE SOLUTION





$\theta_1 = \arctan\left(\frac{1}{2}\right) = 26.56°$ ✓

$\theta_2 = \arctan\left(\frac{8}{5}\right) = 57.99°$ ✓

$$\left.\begin{aligned} F_{1x} &= F_1 \cdot \cos(\theta_1) = 12 \cdot \cos(26.56°) = 10.73 \text{ kips} \checkmark \\ F_{1y} &= F_1 \cdot \sin(\theta_1) = 12 \cdot \sin(26.56°) = 5.36 \text{ kips} \checkmark \\ F_{2x} &= F_2 \cdot \cos(\theta_2) = 8 \cdot \cos(57.99°) = 4.24 \text{ kips} \checkmark \\ F_{2y} &= F_2 \cdot \sin(\theta_2) = 8 \cdot \sin(57.99°) = 6.78 \text{ kips} \checkmark \end{aligned}\right\} \text{Absolute Values}$$

$$\Sigma F_x = 0 \Rightarrow F_{1x} + F_{2x} - F_{Rx} = 0 \Rightarrow F_{Rx} = -10.73 + 4.24 \Rightarrow \boxed{F_{Rx} = -6.49 \text{ kips}} \checkmark$$

$$\Sigma F_y = 0 \Rightarrow F_{1y} + F_{2y} - F_{Ry} = 0 \Rightarrow F_{Ry} = 5.36 + 6.78 \Rightarrow \boxed{F_{Ry} = 12.14 \text{ kips}} \checkmark$$

$$F_R = \sqrt{(F_{Rx})^2 + (F_{Ry})^2} = \sqrt{(12.14)^2 + (-6.49)^2} \Rightarrow \boxed{F_R = 13.77 \text{ kips}} \checkmark$$

$$\theta'_R = \arctan\left(\frac{12.14}{6.49}\right) = 61.87° \qquad \theta_R = 180° - \theta'_R \Rightarrow \boxed{\theta_R = 118.13°} \checkmark$$

ANSWERS

1. (C) $F_R = 13.77$ kips ✓
2. (B) $\theta_R = 118.13°$ ✓
3. (A) $\vec{F}_R = -6.49\vec{i} + 12.14\vec{j}$ ✓

Ioannis,
This solution was excellent!
V. Plevris

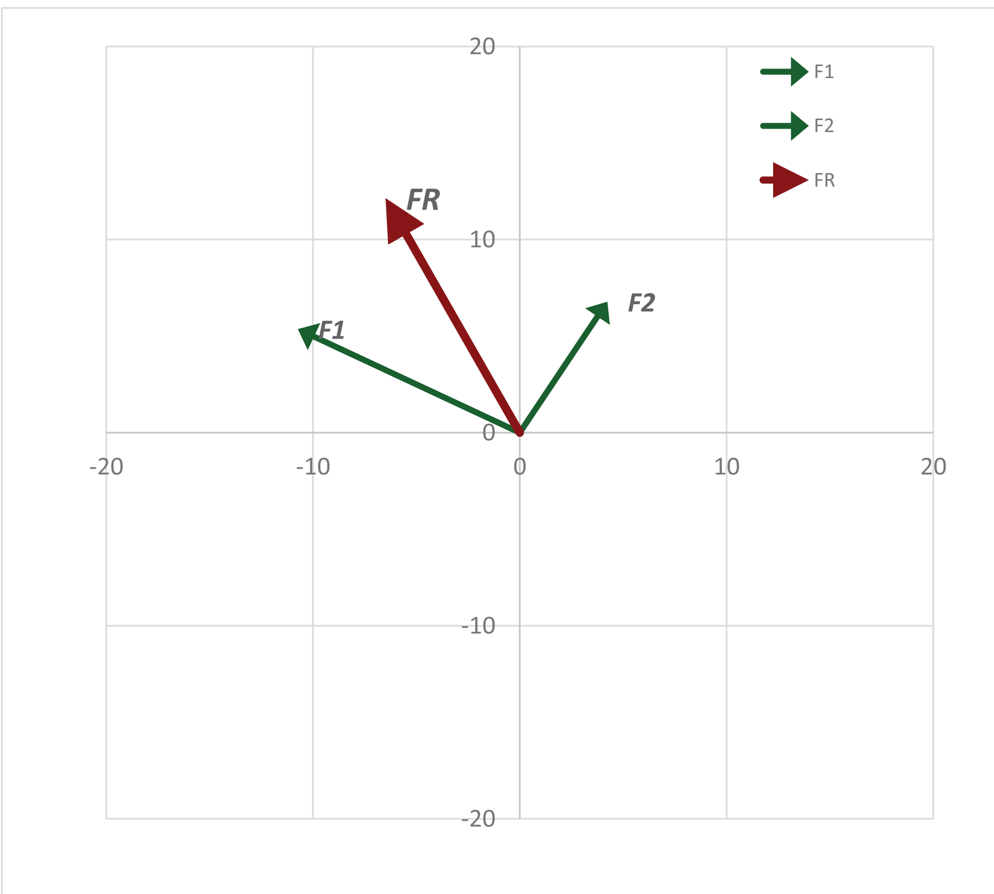
STATICS
CONCURRENT FORCES

Problem: ***CRF-700*** ***Solution in MS Excel***

F	*Magnitude*	*dx*	*dy*	F_x	F_y
1	*12*	*-2*	*1*	*-10.73*	*5.37*
2	*8*	*5*	*8*	*4.24*	*6.78*

$\Sigma F =$ ***-6.49*** ***12.15***

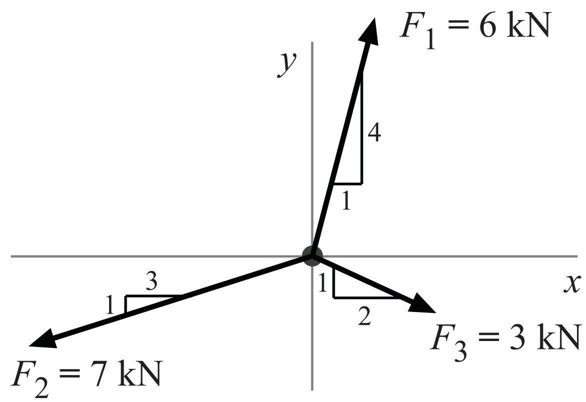
$F_R =$ ***13.78***
$\vartheta =$ *118.12* degrees



STATICS

CONCURRENT FORCES

Problem:



Three forces act as shown in the figure. Using the listed data answer the following:

(1) The magnitude (kN) of the resultant of the three forces is most nearly:

(A) 4.6
(B) 1.2
(C) 6.8
(D) 3.4

(2) The angle (degrees) of the resultant from the x axis is most nearly:

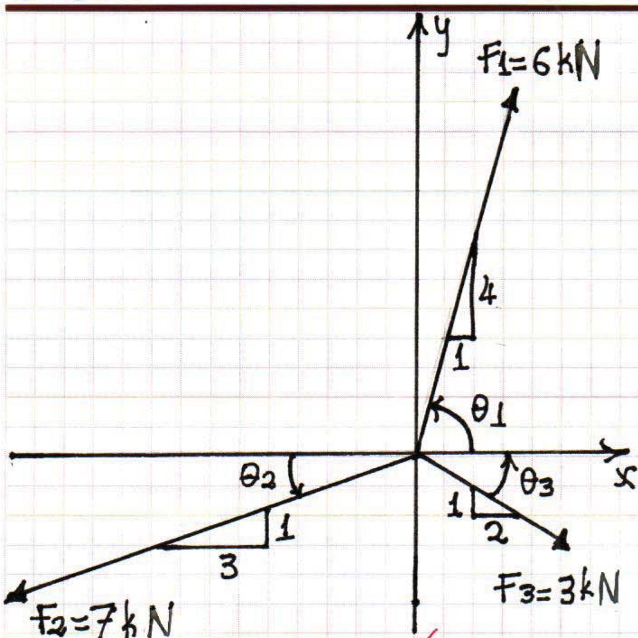
(A) 164
(B) 138
(C) 123
(D) 85

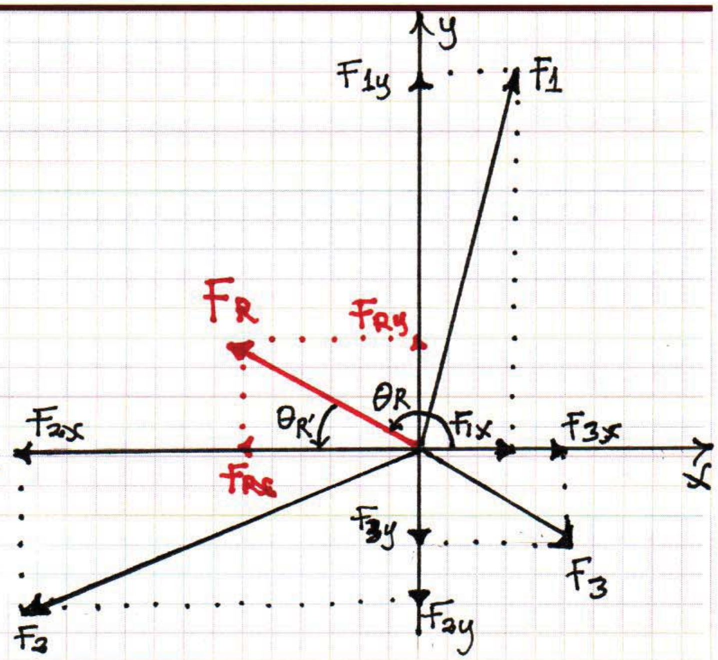
(3) The vector form (kN) of the resultant is most nearly:

(A) - 4.2 **i** + 3.1 **j**
(B) 3.3 **i** - 4.2 **j**
(C) - 2.5 **i** + 2.3 **j**
(D) 6.0 **i** - 2.6 **j**

COMPLETE SOLUTION

CFR-702
PLEVRIS
FALL 2015





$\theta_1 = \alpha\tan\left(\frac{4}{1}\right) = 75.96°$ ✓

$\theta_2 = \alpha\tan\left(\frac{1}{3}\right) = 18.43°$ ✓

$\theta_3 = \alpha\tan\left(\frac{1}{2}\right) = 26.56°$ ✓

$F_{1x} = F_1 \cdot \cos(\theta_1) = 6 \cdot \cos(75.96°) = 1.46\,kN$, ✓ $F_{1y} = F_1 \cdot \sin(\theta_1) = 6 \cdot \sin(75.96°) = 5.82\,kN$ ✓

$F_{2x} = F_2 \cdot \cos(\theta_2) = 7 \cdot \cos(18.43°) = 6.64\,kN$, ✓ $F_{2y} = F_2 \cdot \sin(\theta_2) = 7 \cdot \sin(18.43°) = 2.21\,kN$ ✓

$F_{3x} = F_3 \cdot \cos(\theta_3) = 3 \cdot \cos(26.56°) = 2.68\,kN$, $F_{3y} = F_3 \cdot \sin(\theta_3) = 3 \cdot \sin(26.56°) = 1.34\,kN$ ✓

Abs. Values ✓

$\Sigma F_x = 0 \Rightarrow F_{1x} + F_{2x} + F_{3x} - F_{Rx} = 0 \Rightarrow F_{Rx} = 1.46 - 6.64 + 2.68 \Rightarrow \boxed{F_{Rx} = -2.50\,kN}$

$\Sigma F_y = 0 \Rightarrow F_{1y} + F_{2y} + F_{3y} - F_{Ry} = 0 \Rightarrow F_{Ry} = 5.82 - 2.21 - 1.34 \Rightarrow \boxed{F_{Ry} = 2.27\,kN}$ ✓

$F_R = \sqrt{(F_{Rx})^2 + (F_{Ry})^2} = \sqrt{(-2.50)^2 + (2.27)^2} = 3.38\,kN$ $\boxed{F_R = 3.38\,kN}$ ✓

$\theta'_R = \alpha\tan\left(\frac{2.27}{2.50}\right) = 42.24°$, $\theta_R = 180° - \theta'_R = 180° - 42.24 \Rightarrow \boxed{\theta_R = 137.76°}$ ✓

ANSWERS

1. (D) $F_R = 3.38\,kN$ ✓
2. (B) $\theta_R = 137.76°$ ✓
3. (C) $\vec{F}_R = -2.50\vec{i} + 2.27\vec{j}$ ✓

Excellent!
V. Plevris

STATICS

CONCURRENT FORCES

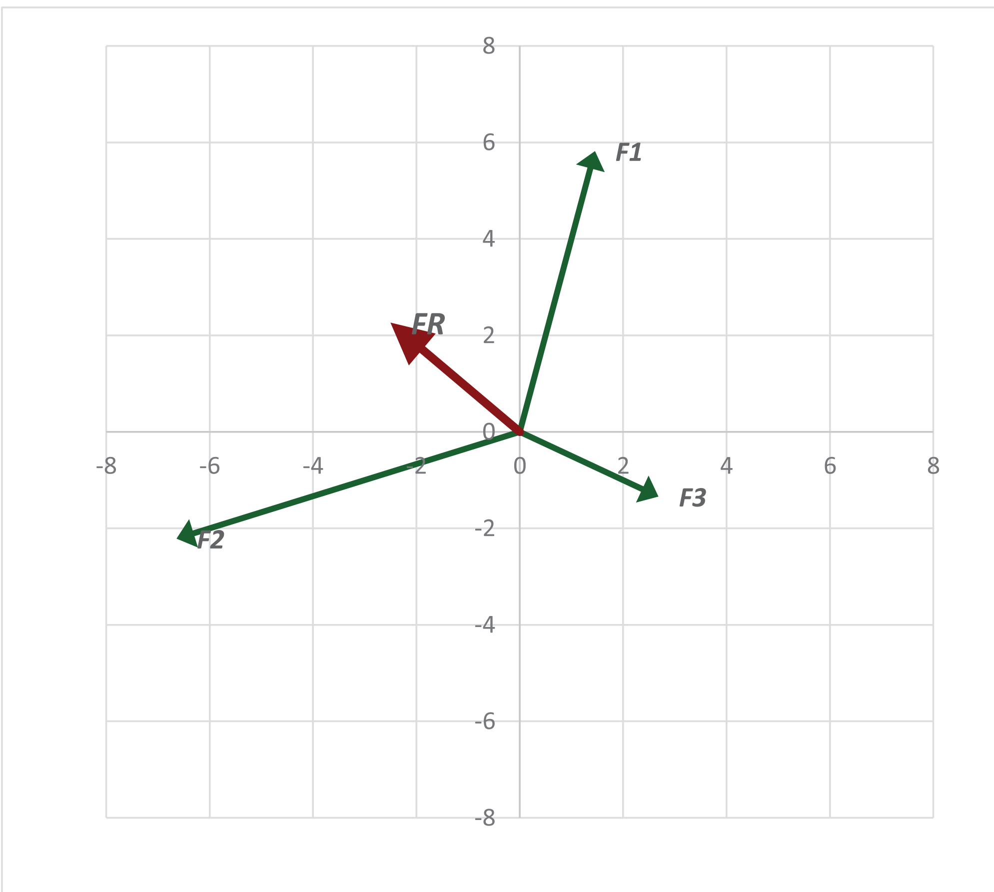
Problem: ***CRF-702*** ***Solution in MS Excel***

F	*Magnitude*	*dx*	*dy*	F_x	F_y
1	6	1	4	1.46	5.82
2	7	-3	-1	-6.64	-2.21
3	3	2	-1	2.68	-1.34

$\Sigma F =$ **-2.50** **2.27**

$F_R =$ **3.38**

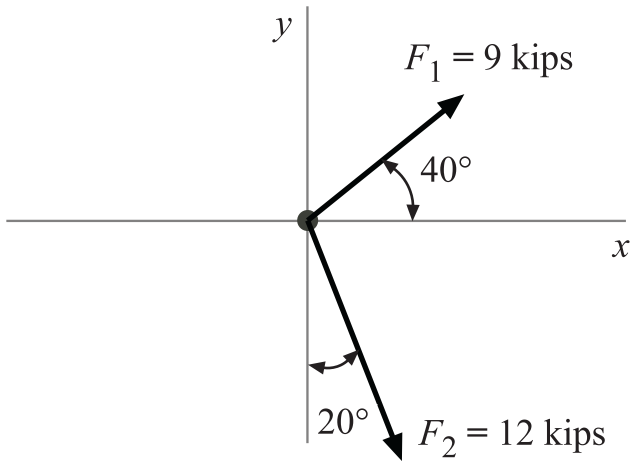
$\vartheta =$ 137.84 degrees



STATICS

CONCURRENT FORCES

Problem:



Two forces act as shown in the figure. Using the listed data answer the following:

(1) The magnitude (kips) of the resultant of the two forces is most nearly:

(A) 10.4
(B) 13.2
(C) 11.0
(D) 12.3

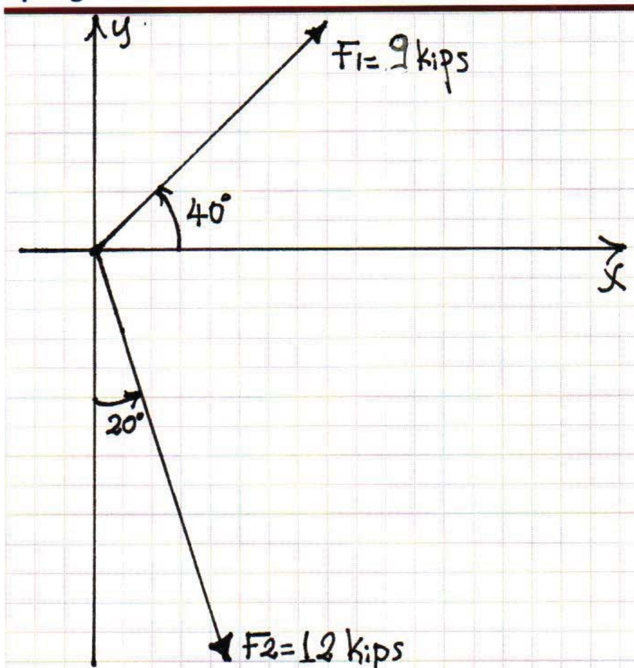
(2) The angle (degrees) of the resultant from the x axis is most nearly:

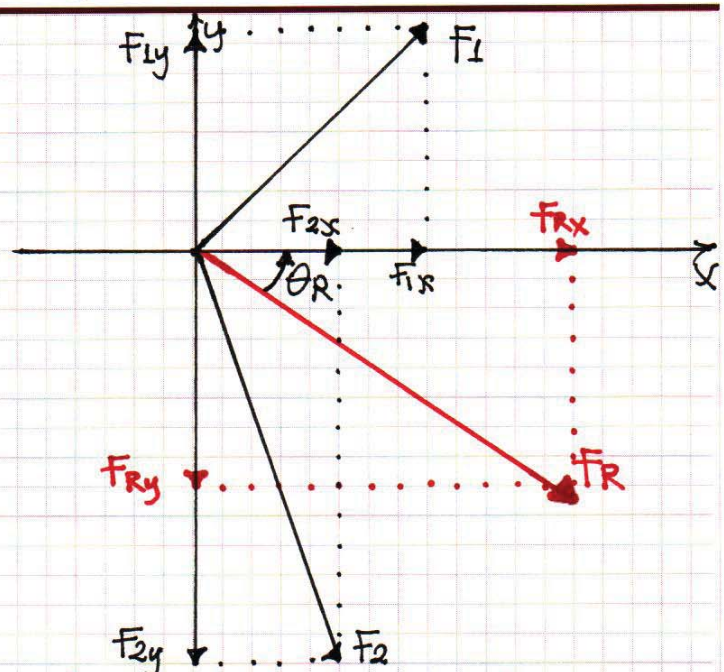
(A) -21
(B) -15
(C) -5
(D) -27

(3) The vector form (kN) of the resultant is most nearly:

(A) 10.3 **i** + 7.7 **j**
(B) 11.0 **i** - 5.5 **j**
(C) 12.5 **i** + 4.8 **j**
(D) 11.9 **i** - 2.4 **j**

COMPLETE SOLUTION





$$\left.\begin{aligned}
F_{1x} &= F_1 \cdot \cos(40°) = 9 \cdot \cos(40) = 6.89 \text{ kips} \\
F_{1y} &= F_1 \cdot \sin(40°) = 9 \cdot \sin(40) = 5.79 \text{ kips} \\
F_{2x} &= F_2 \cdot \sin(20°) = 12 \cdot \sin(20°) = 4.10 \text{ kips} \\
F_{2y} &= F_2 \cdot \cos(20°) = 12 \cdot \cos(20°) = 11.28 \text{ kips}
\end{aligned}\right\} \text{Absolute Values}$$

$\Sigma F_x = 0 \Rightarrow F_{1x} + F_{2x} - F_{Rx} = 0 \Rightarrow F_{Rx} = 6.89 + 4.10 \Rightarrow \boxed{F_{Rx} = 10.99 \text{ kips}}$

$\Sigma F_y = 0 \Rightarrow F_{1y} + F_{2y} - F_{Ry} = 0 \Rightarrow F_{Ry} = 5.79 - 11.28 \Rightarrow \boxed{F_{Ry} = -5.49 \text{ kips}}$

$F_R = \sqrt{(F_{Rx})^2 + (F_{Ry})^2} = \sqrt{(10.99)^2 + (-5.49)^2} \Rightarrow \boxed{F_R = 12.28 \text{ kips}}$

$\theta_R = atan\left(\frac{5.49}{10.99}\right) = 26.54° \quad \boxed{\theta_R = 26.54°}$

<u>ANSWERS</u>

1. (D) $F_R = 12.28$ kips
2. (D) $\theta_R = 26.54°$
3. (B) $\vec{F_R} = 10.99\vec{i} - 5.49\vec{j}$

Great job!
V. Plevris

STATICS

CONCURRENT FORCES

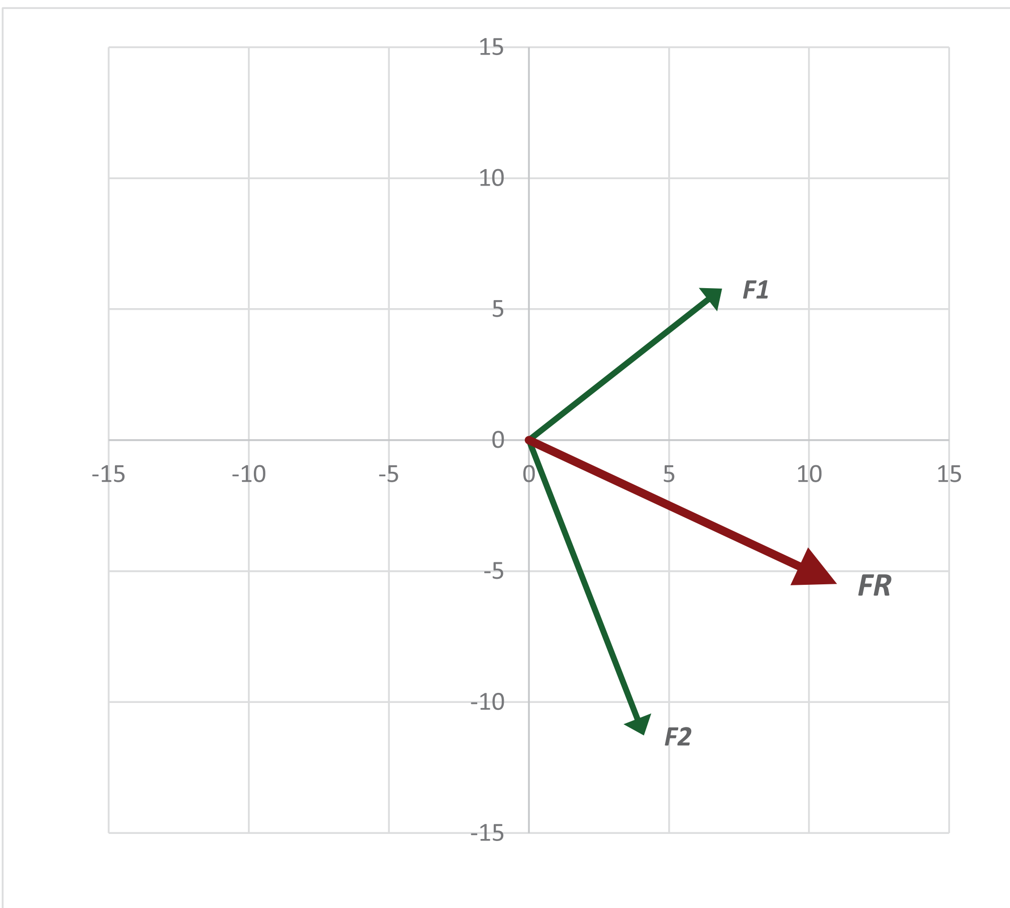
Problem: ***CRF-704*** ***Solution in MS Excel***

F	*Magnitude*	*Direction (deg)*	F_x	F_y
1	9	40	6.89	5.79
2	12	-70	4.10	-11.28

$\Sigma F =$ **11.00** **-5.49**

$F_R =$ **12.29**

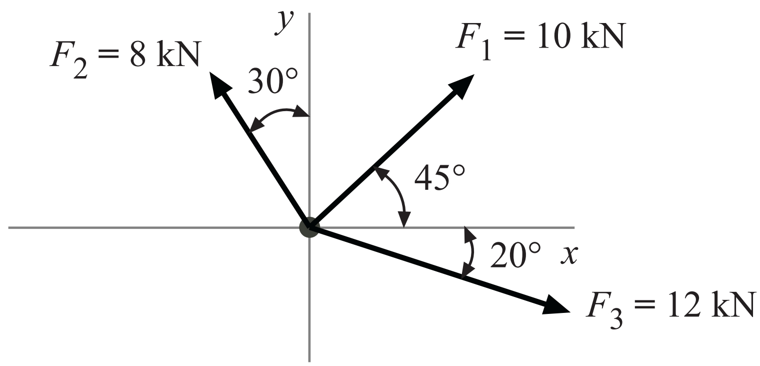
$\vartheta =$ -26.53 degrees



STATICS

CONCURRENT FORCES

Problem:



Three forces act as shown in the figure. Using the listed data answer the following:

(1) The magnitude (kN) of the resultant of the three forces is most nearly:

(A) 13.3
(B) 15.2
(C) 17.4
(D) 19.6

(2) The angle (degrees) of the resultant from the x axis is most nearly:

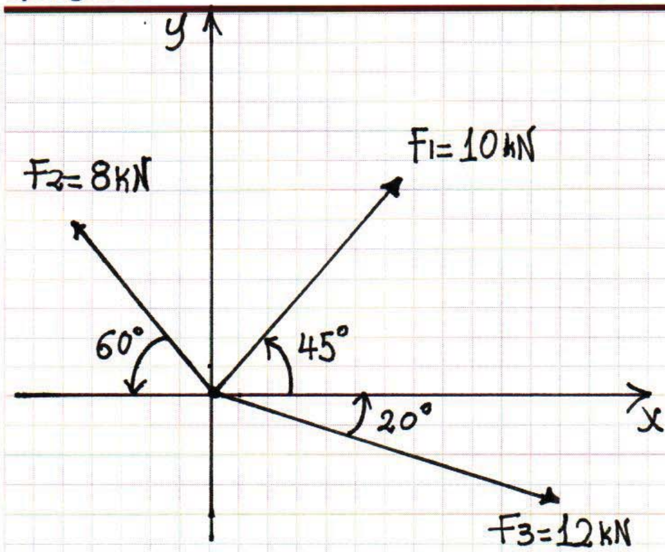
(A) 55
(B) 44
(C) 35
(D) 16

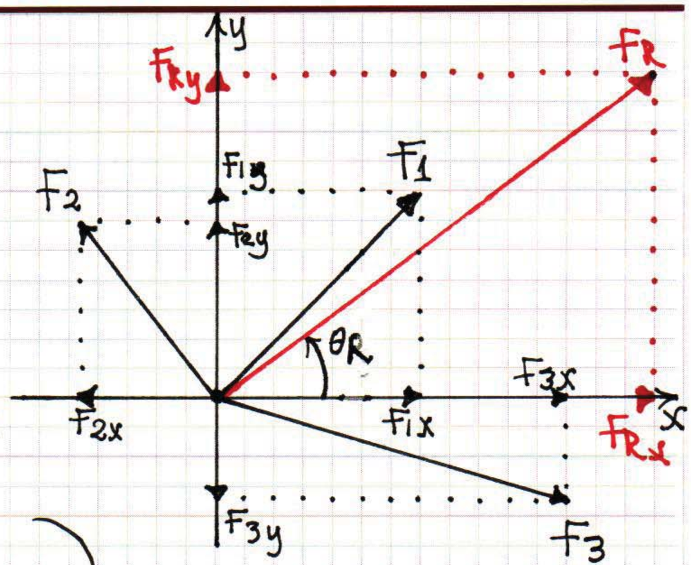
(3) The vector form (kN) of the resultant is most nearly:

(A) 14.3 **i** + 9.9 **j**
(B) 11.2 **i** + 8.5 **j**
(C) 10.5 **i** + 6.9 **j**
(D) 13.1 **i** + 7.2 **j**

COMPLETE SOLUTION

CFR-706
PLEVRIS
FALL 2015





$F_{1x} = F_1 \cdot \cos(45°) = 10 \cdot \cos(45°) = 7.07\ kN$ ✓

$F_{1y} = F_1 \cdot \sin(45°) = 10 \cdot \sin(45°) = 7.07\ kN$ ✓

$F_{2x} = F_2 \cdot \cos(60°) = 8 \cdot \cos(60°) = 4.00\ kN$ ✓

$F_{2y} = F_2 \cdot \sin(60°) = 8 \cdot \sin(60°) = 6.93\ kN$ ✓

$F_{3x} = F_3 \cdot \cos(20°) = 12 \cdot \cos(20°) = 11.28\ kN$ ✓

$F_{3y} = F_3 \cdot \sin(20°) = 12 \cdot \sin(20°) = 4.10\ kN$ ✓

Absolute Values ✓

$\Sigma F_x = 0 \Rightarrow F_{1x} + F_{2x} + F_{3x} - F_{Rx} = 0 \Rightarrow F_{Rx} = 7.07 - 4.00 + 11.28 \Rightarrow \boxed{F_{Rx} = 14.35\ kN}$ ✓

$\Sigma F_y = 0 \Rightarrow F_{1y} + F_{2y} + F_{3y} - F_{Ry} = 0 \Rightarrow F_{Ry} = 7.07 + 6.93 - 4.10 \Rightarrow \boxed{F_{Ry} = 9.90\ kN}$ ✓

$F_R = \sqrt{(F_{Rx})^2 + (F_{Ry})^2} = \sqrt{(14.35)^2 + (9.90)^2} = 17.43\ kN \qquad \boxed{F_R = 17.43\ kN}$ ✓

$\theta_R = atan\left(\frac{9.90}{14.35}\right) = 34.60° \qquad \boxed{\theta_R = 34.60°}$ ✓

<u>ANSWERS</u>

1. (C) $F_R = 17.43\ kN$ ✓
2. (C) $\theta_R = 34.60°$ ✓
3. (A) $\vec{F_R} = 14.35\vec{i} + 9.90\vec{j}$ ✓

Excellent solution Ioannis!
V. Plevris

STATICS

CONCURRENT FORCES

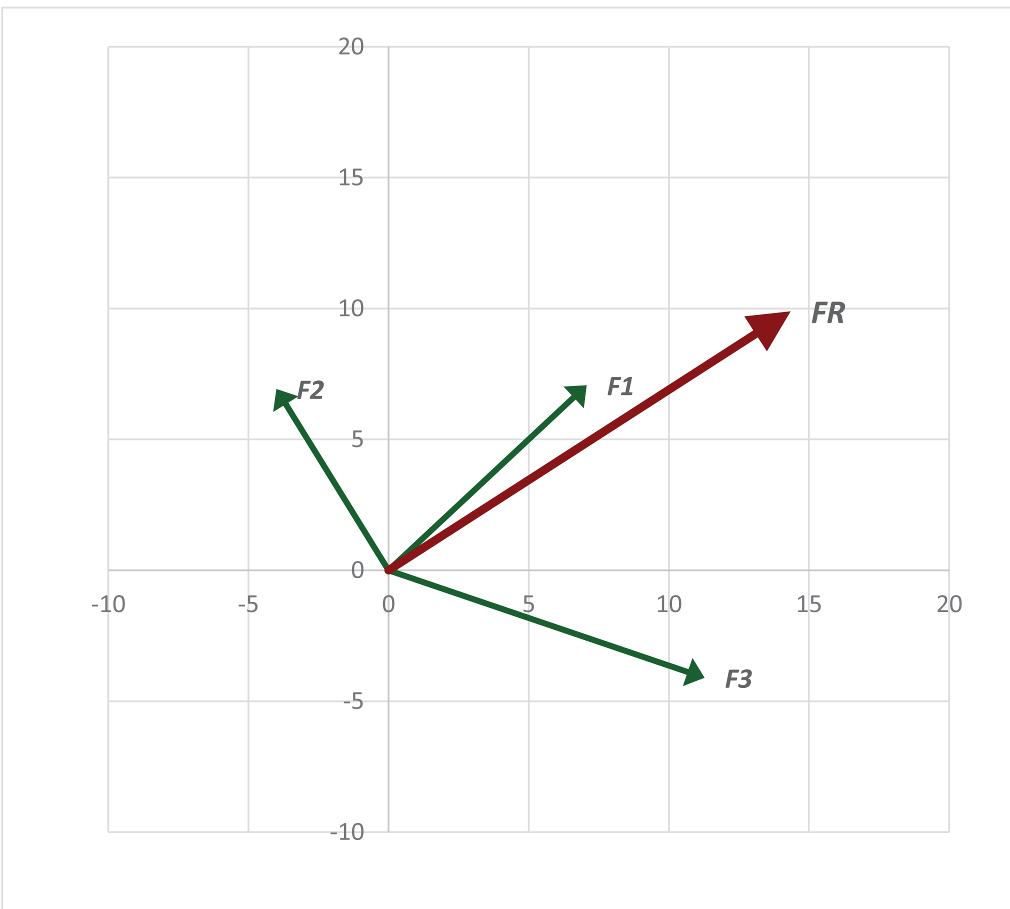
Problem: ***CRF-706*** ***Solution in MS Excel***

F	*Magnitude*	*Direction (deg)*	F_x	F_y
1	*10*	*45*	*7.07*	*7.07*
2	*8*	*120*	*-4.00*	*6.93*
3	*12*	*-20*	*11.28*	*-4.10*

$\Sigma F =$ ***14.35*** ***9.90***

$F_R =$ ***17.43***

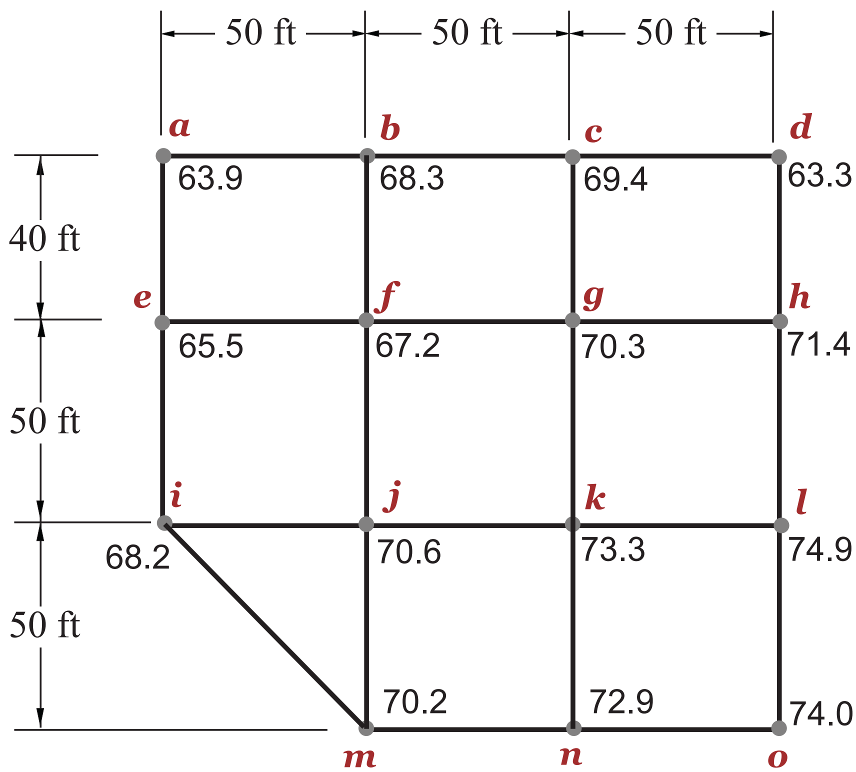
$\vartheta =$ *34.59* degrees



VOLUME COMPUTATIONS

BORROW PITS

Problem: (Borrow Pit)



The final elevation of the area level is desired to be **60.0**.

The numbers shown are the elevations of the corners (ft) and the *balance factor* will be neglected.

An area has been laid out as shown above. The volume of cut in cubic yards to grade the area level to the final elevation of **60.0** ft is most nearly:

(a) 6824
(b) 7195
(c) 6981
(d) 7404

SOLUTION NEXT PAGE

VOLUME COMPUTATIONS
BORROW PITS

Problem: ***BRRW-16*** ***Solution in MS Excel***

Since elevations are given, we need to determine the Corner Cuts (CC) as show below:

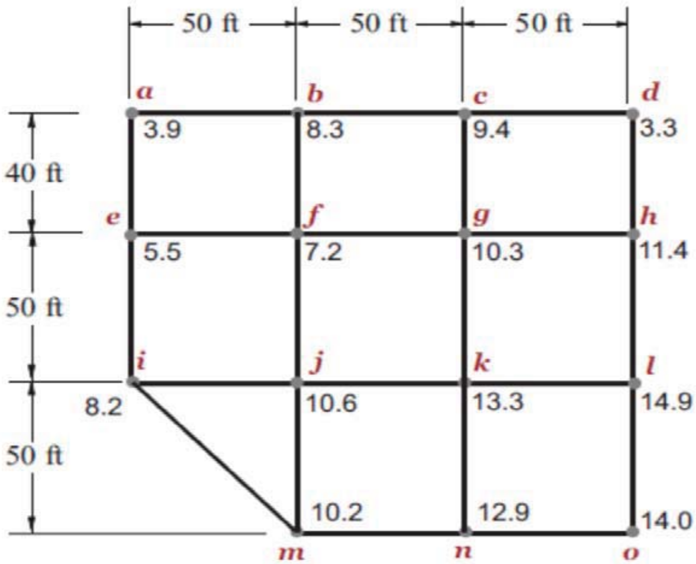


Figure	Sum of Corner Cuts (ft^2)	Area of Figure (ft^2)	Multiplier (1/4 or 1/3)	Volume (ft^3)
adhe	*94.5*	*2000*	*0.25*	*47,250.00*
ehonmji	*224.9*	*2500*	*0.25*	*140,562.50*
ijm	*29*	*1250*	*0.333333333*	*12,083.33*

Sum = ***199,896*** **ft^3**

V ≈ ***7,404*** **yd^3**

Analytical calculations (Sum of Corner Cuts):

94.5 *=3.9+8.3*2+9.4*2+3.3+11.4+10.3*2+7.2*2+5.5*

224.9 *=5.5+7.2*2+10.3*2+11.4+14.9*2+14+12.9*2+10.2+10.6*3+8.2+13.3*4*

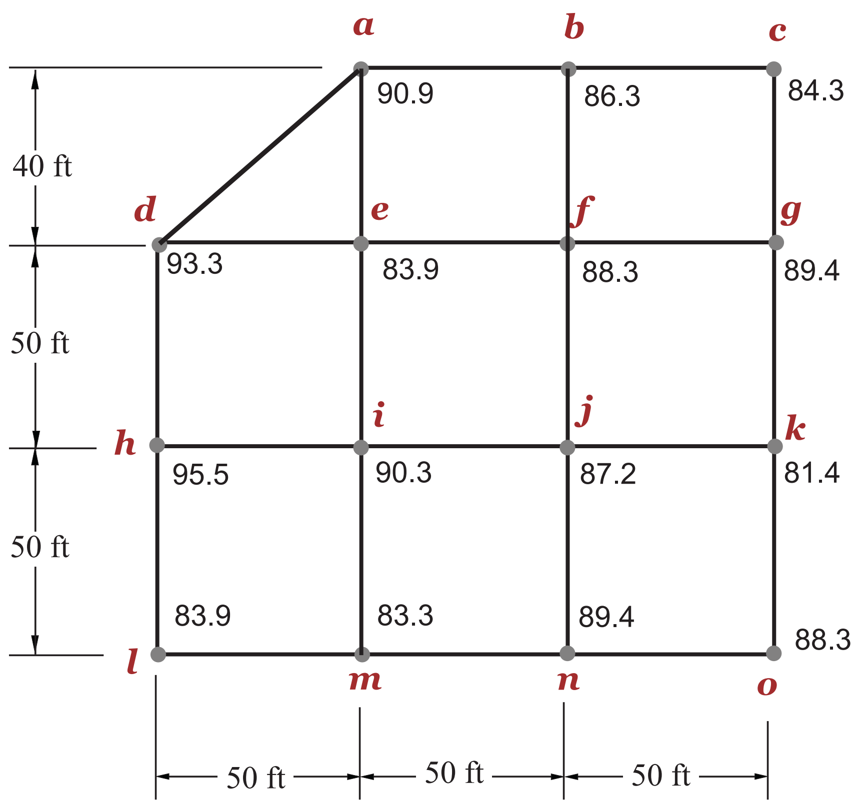
29 *=8.2+10.6+10.2*

BRRW-16-Ans
PLEVRIS
FALL 2015

VOLUME COMPUTATIONS

BORROW PITS

Problem: (Borrow Pit)



The final elevation of the area level is desired to be **80.0**.

The numbers shown are the elevations of the corners (ft) and the *balance factor* will be neglected.

An area has been laid out as shown above. The volume of cut in cubic yards to grade the area level to the final elevation of **80.0** ft is most nearly:

(a) 5973
(b) 5789
(c) 5514
(d) 6138

SOLUTION NEXT PAGE

VOLUME COMPUTATIONS
BORROW PITS

Problem: BRRW-18 Solution in MS Excel

Since elevations are given, we need to determine the Corner Cuts (CC) as show below:

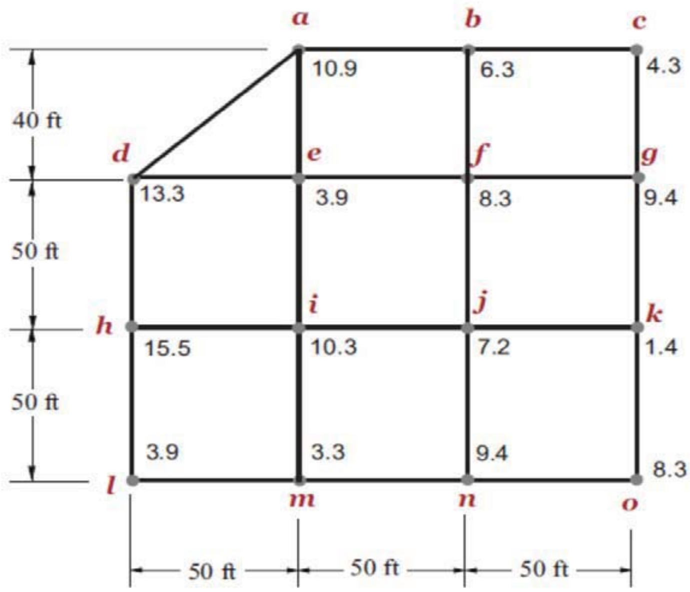


Figure	Sum of Corner Cuts (ft^2)	Area of Figure (ft^2)	Multiplier (1/4 or 1/3)	Volume (ft^3)
acge	57.7	2000	0.25	28,850.00
dgol	188.5	2500	0.25	117,812.50
aed	28.1	1000	0.333333333	9,366.67

Sum = ***156,029*** **ft^3**

V ≈ 5,779 **yd^3**

Analytical calculations (Sum of Corner Cuts):

57.7 *=10.9+6.3*2+4.3+9.4+8.3*2+3.9*

188.5 *=13.3+3.9*2+8.3*2+9.4+1.4*2+8.3+9.4*2+3.3*2+3.9+15.5*2+10.3*4+7.2*4*

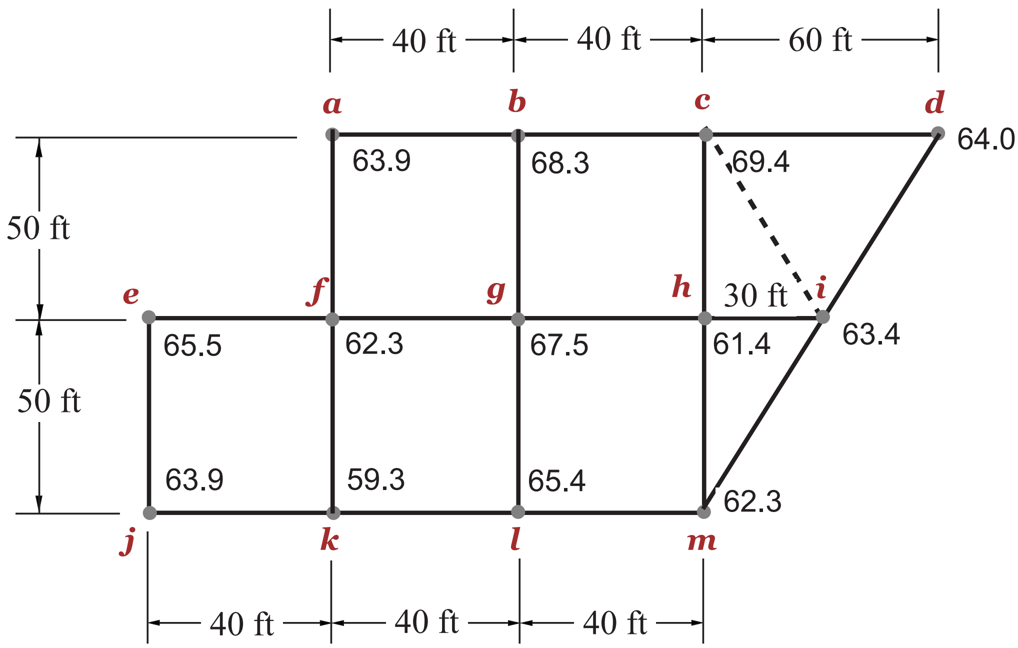
28.1 *=13.3+10.9+3.9*

BRRW-18-Ans
PLEVRIS
FALL 2015

VOLUME COMPUTATIONS

BORROW PITS

Problem: (Borrow Pit)



The final elevation of the area level is desired to be **50.0**.

The numbers shown are the elevations of the corners (ft) and the *balance factor* will be neglected.

An area has been laid out as shown above. The volume of cut in cubic yards to grade the area level to the final elevation of **50.0** ft is most nearly:

(a) 7148
(b) 6802
(c) 7003
(d) 6912

SOLUTION NEXT PAGE

VOLUME COMPUTATIONS
BORROW PITS

Problem: BRRW-20 Solution in MS Excel

Since elevations are given, we need to determine the Corner Cuts (CC) as show below:

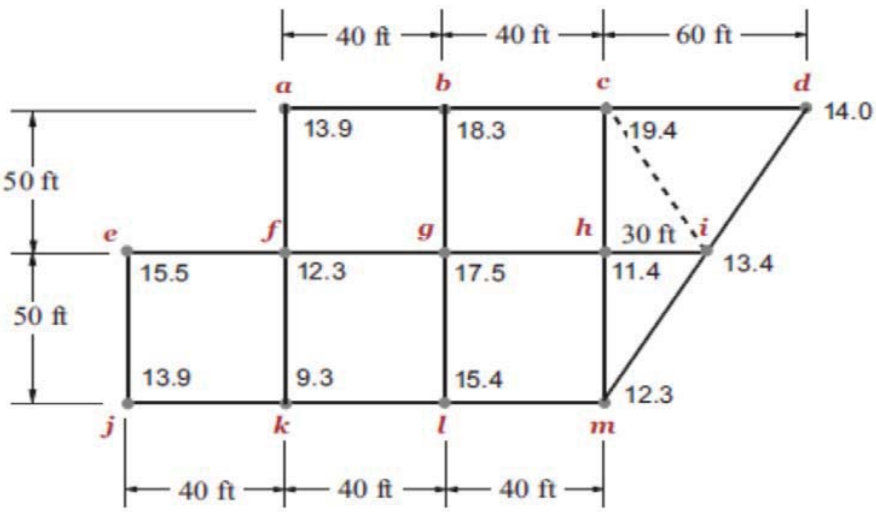


Figure	*Sum of Corner Cuts (ft^2)*	*Area of Figure (ft^2)*	*Multiplier (1/4 or 1/3)*	*Volume (ft^3)*
acmjef	*290.7*	*2000*	*0.25*	*145,350.00*
cdi	*46.8*	*1500*	*0.333333333*	*23,400.00*
cih	*44.2*	*750*	*0.333333333*	*11,050.00*
him	*37.1*	*750*	*0.333333333*	*9,275.00*

Sum = ***189,075*** **ft^3**

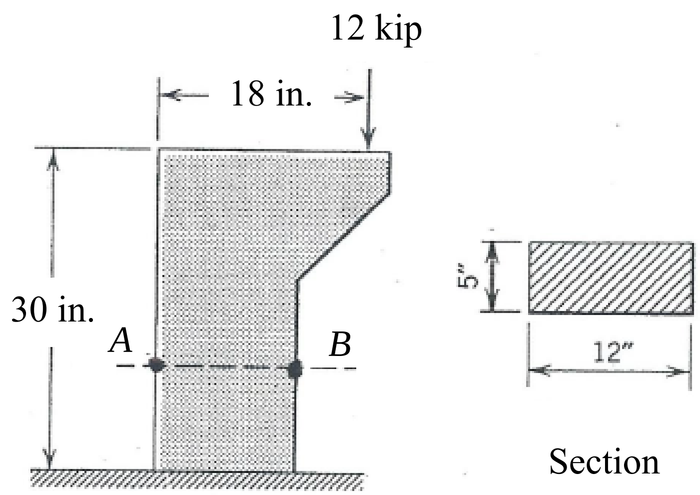
V ≈ ***7,003*** **yd^3**

Analytical calculations (Sum of Corner Cuts):

290.7 *=13.9+18.3*2+19.4+11.4*2+12.3+15.4*2+9.3*2+13.9+15.5+12.3*3+17.5*4*
46.8 *=19.4+14+13.4*
44.2 *=19.4+13.4+11.4*
37.1 *=11.4+13.4+12.3*

MECHANICS OF SOLIDS

COMBINED STRESS (N + M)



A 30-in. long post is loaded as shown in the figure. Using the the given cross-section answer the following:

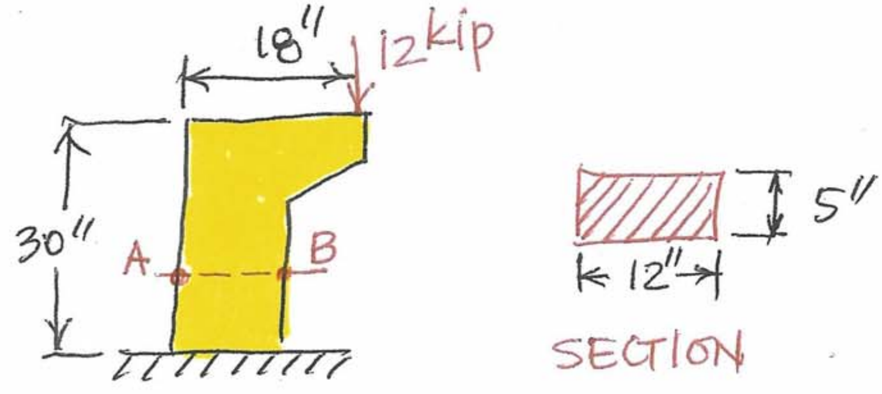
(A) The normal stress (psi) at point *A* is most nearly:

(A) 1000 (T)
(B) 1250 (T)
(C) 1000 (C)
(D) 1250 (C)

(B) The normal stress (psi) at point *B* is most nearly:

(A) 1400 (T)
(B) 1900 (T)
(C) 1400 (C)
(D) 1900 (C)

Problem: (Combined Stress)



Determine the distribution of normal stress on section AB.

(1) Normal stress at point A

$P = 12{,}000$ LB

$M = 12{,}000(12") = 144{,}000$ LB·IN

$A = (5)(12) = 60\ in^2$

$I = (5)(12)^3/12 = 720\ in^4$

1200

200

$$\sigma_A = -\frac{P}{A} + \frac{M}{I}c = -\frac{12000}{60} + \frac{144{,}000(6")}{720}$$

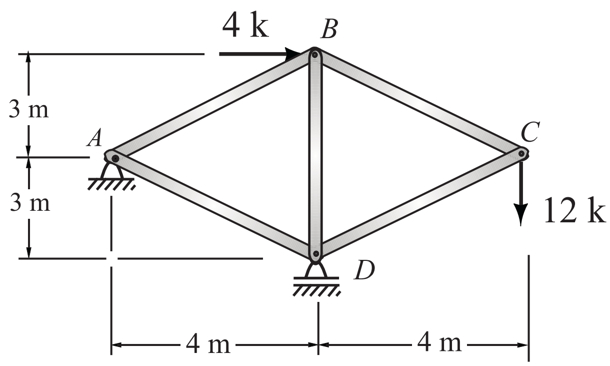
$\boxed{\sigma_A = +1000 \text{ psi}}$ (Tension)

$$\sigma_B = -\frac{P}{A} - \frac{M}{I}c = \frac{-12000}{60} - \frac{144{,}000(6")}{720}$$

$\boxed{\sigma_B = -1400 \text{ psi}}$ (Compression)

STATICS / MECHANICS OF MATERIAL

DETERMINATE TRUSSES



Support A : Pin
Support D : Roller

A plane truss system is loaded as shown. Using the listed data and the support conditions, answer the following questions:

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

(A) 25.00 (C)
(B) 20.25 (T)
(C) 18.00 (C)
(D) 15.00 (T)

$F_{AB} = ?$

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

(A) 35.00 (C)
(B) 25.25 (T)
(C) 10.00 (C)
(D) 12.00 (T)

$F_{AD} = ?$

(3) the member force (kN) in member *BD* is most nearly

(A) 15.00 (C)
(B) 20.00 (T)
(C) 22.00 (C)
(D) 26.00 (T)

$F_{BD} = ?$

TRSS-309
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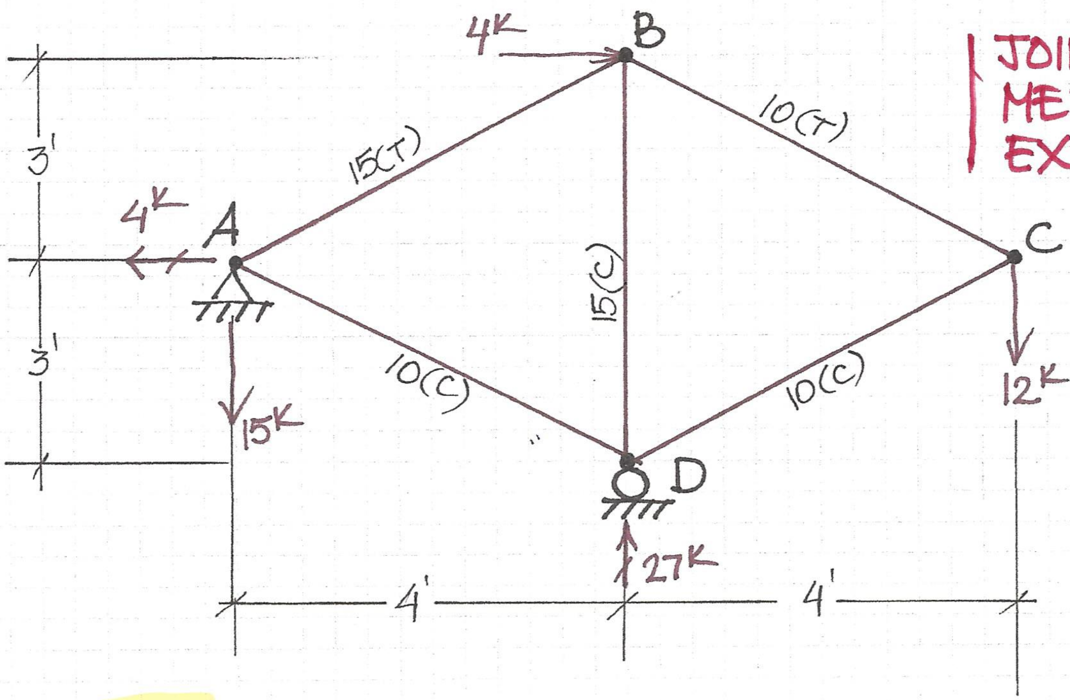
FALL 2014

COMPLETE SOLUTION



JOINT METHOD EXAMPLE

$\circlearrowright A \quad \Sigma M = 0$

$(4^K)(3') + (12^K)(8') = 4D_y$

$12 + 96 = 4D_y$

$D_y = 27^K \uparrow$

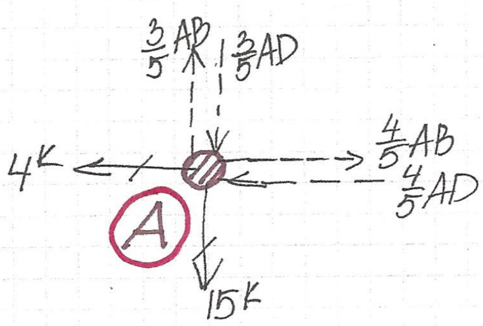
VERY GOOD!

$\circlearrowleft \quad \Sigma M = 0$

$(12^K)(4') + (4^K)(6') - (4^K)(3') = 4A_y$

$48 + 24 - 12 = 4A_y$

$A_y = +15^K \downarrow$



$+\uparrow \Sigma F_y = 0$

$0.6AB + 0.6AD = 15$

$0.6X + 0.6Y = 15$

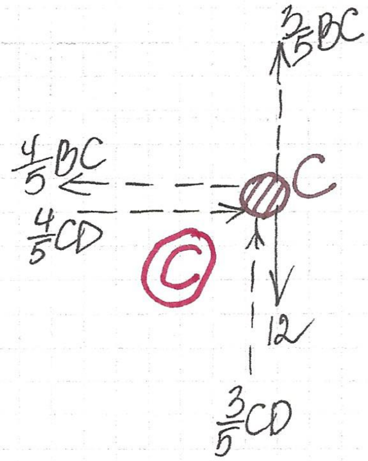
$AB = X = 15^k$

$AD = Y = 10^k$

$\xrightarrow{+} \Sigma F_x = 0$

$0.8AB - 0.8AD = 4$

$0.8X - 0.8Y = 4$



$+\uparrow \sum F_y = 0$

$(0.6) \cdot BC + 0.6\,CD = 12$

$0.6x + 0.6y = 12$

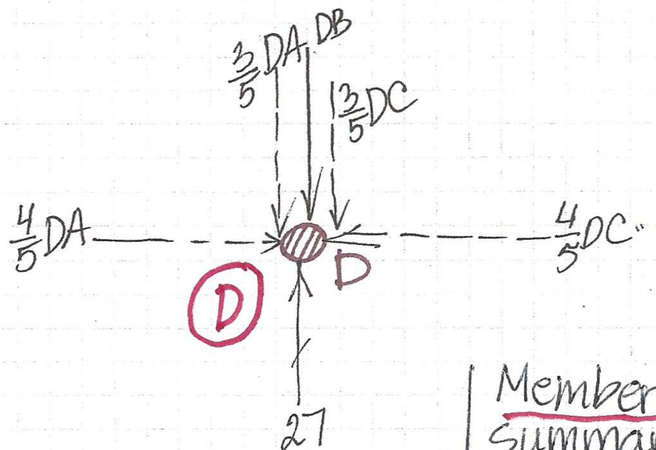
$BC = x = 10^k$ (T)

$CD = y = 10^k$ (C)

$\xrightarrow{+} \sum F_x = 0$

$0.8\,CD = 0.8\,BC$

$0.8\,CD - 0.8\,BC = 0$



$+\uparrow \sum F_y = 0$

$27 = 0.6\,DA + DB + 0.6\,DC$

$27 = (0.6)(10) + DB + (0.6)(10)$

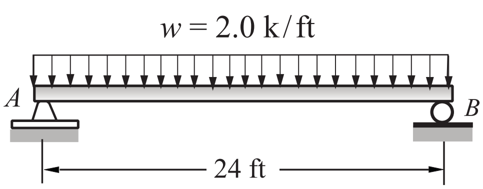
$DB = 15\,k$ (C)

Member forces are summarized in Fig. 1.

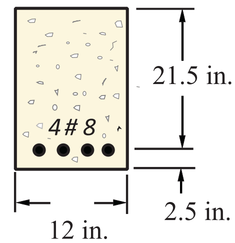
EXCELLENT WORK! AZ

TRANSFORMED AREA METHOD

REINFORCED CONCRETE BEAM



n = 10
(Modular Ratio = 10)



Section

A reinforced concrete beam is loaded as shown in the figure. Assume the weight of the beam is included in the uniform load and the sections have ***cracked***. Using the Transformed Area Method (*TAM*), answer the following:

(1) the max. compressive stress (psi) in concrete is most nearly

(A) 2400
(B) 2250
(C) 2140
(D) 1850

$f_c = ?$

(2) the max. tensile stress (psi) in steel is most nearly

(A) 32,600
(B) 29,400
(C) 26,350
(D) 24,500

$f_s = ?$

RC-788
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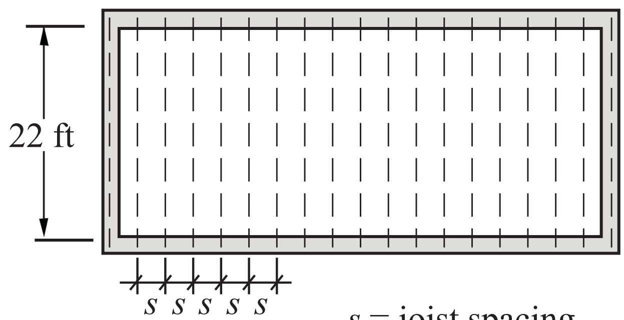
DESIGN OF STEEL STRUCTURES

OPEN WEB STEEL JOISTS

JORDAN MATTHEWS

Problem:



s = 4′- 0″

s = joist spacing
L = joist span

4″ Floor Slab (R/C)
Other Dead Load = 8 psf
Live Load = 60 psf
Max. *LL* Deflection = *L* / 360

L = 22′- 0″
s = 4′- 0″

A floor system consists of open-web steel joists spaced at 4 ft and spanning 22 ft as shown in figure. Assume the slab provides continuous lateral support. Using the listed data and the attached joist table from SJI, answer the following:

(1) Total factored uniform load (lb/ft) on one joist is most nearly

(A) 780
(B) 682
(C) 554
(D) 480

(2) The most economical K-series joist using the SJI's joist tables

(A) 12K5
(B) 14K4
(C) 16K5
(D) 20K3

COMPLETE SOLUTION

OWSJ-68
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Jordan, this problem was custom-made just for you!

STANDARD LOAD TABLE FOR OPEN WEB STEEL JOISTS

K-SERIES

LRFD

STANDARD LOAD TABLE FOR OPEN WEB STEEL JOISTS, K-SERIES
Based On A 50 ksi Maximum Yield Strength - Loads Shown In Pounds Per Linear Foot (plf)

Joist Designation	10K1	12K1	12K3	12K5	14K1	14K3	14K4	14K6
Depth (in.)	10	12	12	12	14	14	14	14
Approx. Wt (lbs./ft.)	5.0	5.0	5.7	7.1	5.2	6.0	6.7	7.7
Span (ft.) ↓								
10	825 550							
11	825 542							
12	825 455	825 550	825 550	825 550				
13	718 363	825 510	825 510	825 510				
14	618 289	750 425	825 463	825 463	825 550	825 550	825 550	825 550
15	537 234	651 344	814 428	825 434	766 475	825 507	825 507	825 507
16	469 192	570 282	714 351	825 396	672 390	825 467	825 467	825 467
17	415 159	504 234	630 291	825 366	592 324	742 404	825 443	825 443
18	369 134	448 197	561 245	760 317	528 272	661 339	795 397	825 408
19	331 113	402 167	502 207	681 269	472 230	592 287	712 336	825 383
20	298 97	361 142	453 177	613 230	426 197	534 246	642 287	787 347
21		327 123	409 153	555 198	385 170	483 212	582 248	712 299
22		298 106	373 132	505 172	351 147	439 184	529 215	648 259
23		271 93	340 116	462 150	321 128	402 160	483 188	592 226
24		249 81	312 101	423 132	294 113	367 141	442 165	543 199
25					270 100	339 124	408 145	501 175
26					249 88	313 110	376 129	462 156
27					231 79	289 98	349 115	427 139
28					214 70	270 88	324 103	397 124
29								
30								

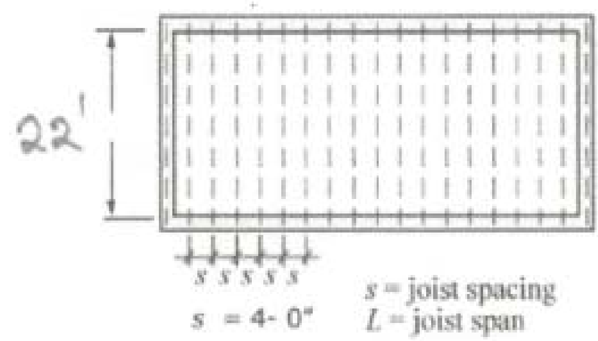
Joist Designation	16K2	16K3	16K4	16K5	16K6	16K7	16K9
Depth (in.)	16	16	16	16	16	16	16
Approx. Wt (lbs./ft.)	5.5	6.3	7.0	7.5	8.1	8.6	10.0
Span (ft.) ↓							
10							
11							
12							
13							
14							
15							
16	825 550	825 550	825 550	825 550	825 550	825 550	825 550
17	768 488	825 526	825 526	825 526	825 526	825 526	825 526
18	684 409	762 456	825 490	825 490	825 490	825 490	825 490
19	612 347	682 386	820 452	825 455	825 455	825 455	825 455
20	552 297	615 330	739 386	825 426	825 426	825 426	825 426
21	499 255	556 285	670 333	754 373	822 405	825 406	825 406
22	454 222	505 247	609 289	687 323	747 351	825 385	825 385
23	415 194	462 216	556 252	627 282	682 307	760 339	825 363
24	381 170	424 189	510 221	576 248	627 269	697 298	825 346
25	351 150	390 167	469 195	529 219	576 238	642 263	771 311
26	324 133	360 148	433 173	489 194	532 211	592 233	711 276
27	300 119	334 132	402 155	453 173	493 188	549 208	658 246
28	279 106	310 118	373 138	421 155	459 168	510 186	612 220
29	259 95	289 106	348 124	391 139	427 151	475 167	570 198
30	241 86	270 96	324 112	366 126	399 137	444 151	532 178

DESIGN OF STEEL STRUCTURES

QUIZ

April 3, 2014

JORDAN



Floor Slab (R/C)
Other Dead Load = 8 psf
Live Load = 60 psf
Max. LL Deflection = L/360

A floor system consists of open-web steel joists spaced at 4 ft and spanning 22 ft as shown in figure. Assume the slab provides continuous lateral support. Using the listed data select a K-series joist.

weight of floor slab: 4/12 ft × 150 lb/ft³ = 50 psf
Other dead load: 8 psf | joist weight: 4.0 psf (estimate)

Total Dead Load: 62.0 psf

Uniform Dead Load (w_{DL})

w_{DL} = DL × joist spacing
= 62.0 psf × 4.0 ft
= 248 lb/ft

Uniform Live Load (w_{LL})

w_{LL} = LL × joist spacing
= 60 psf × 4.0 ft
= 240 lb/ft

Factored Load (w_u)

$w_u = 1.2w_{DL} + 1.6w_{LL}$
= 1.2(248) + 1.6(240)
= 681.6 lb/ft

Span: L = 22 ft
w_u = 681.6 lb/ft

12K5 ✗
14K6 ✗
16K5 (weight = 7.5 lb/ft) ←

★ No restriction was placed on depth so we choose 16K5, which has a load carrying capacity of 687 lb/ft > 681.6 lb/ft

Approx. weight of 16K5
weight = 7.5/4 = 1.87 psf < 4 psf (initial estimate)

Live Load Deflection

16K5 $\boxed{\begin{matrix}687\\323\end{matrix}}$
L = 22 ft

Max. Live Load Deflection = L/360 = 22/360 = 0.06 ft
From joist table: (LL max) = 323 lb/ft
Service Live Load = 240 lb/ft
323 lb/ft > 240 lb/ft (OK)

USE 16K5 STEEL JOIST

EXCELLENT SOLUTION
Z