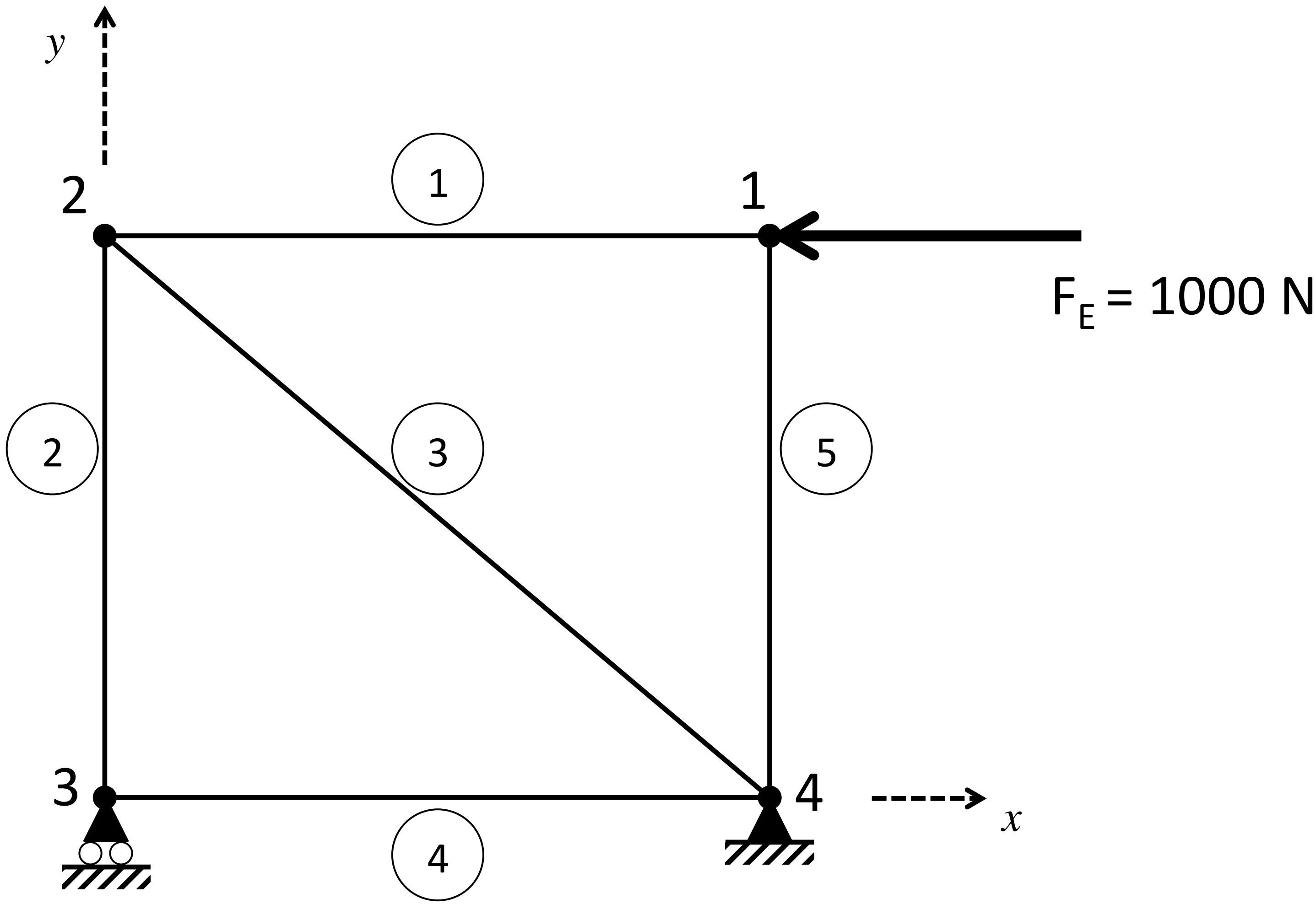
Lab 2 – Truss Design

2D truss code

Example



1, 2, 3, and 4 are the joints

1, 2, 3, 4, and 5 are the members

Assume length of each member is the same for this example.

Method of Joint – FBD for each joint

For this system

$\mathbf{u_1}$ = -**i**

$\mathbf{u_2}$ = -**j**

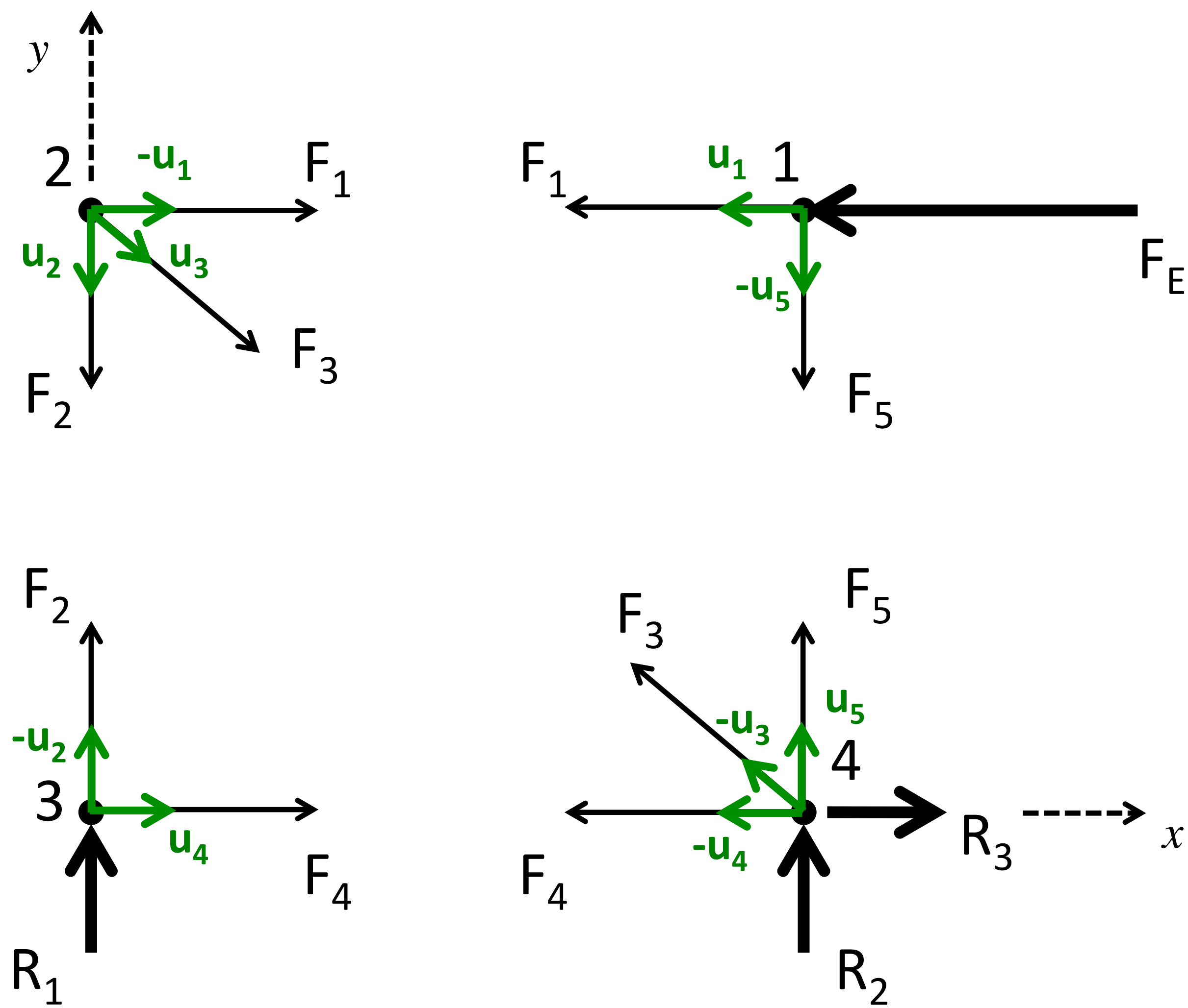
$\mathbf{u_3}$ = u_{3x} **i** + u_{3y} **j**

= cos 45° **i**

- sin 45° **j**

$\mathbf{u_4}$ = **i**

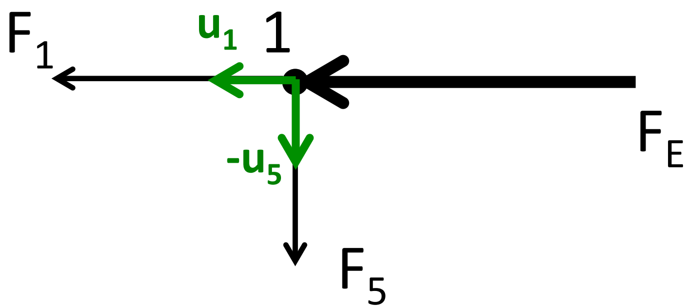
$\mathbf{u_5}$ = **j**



$F_\#$ = magnitude of force in member #

R = Reaction force at support

Equilibrium of Joint 1



$$\sum F_x = 0:$$

$$F_1 u_1 + F_E u_1 = 0$$

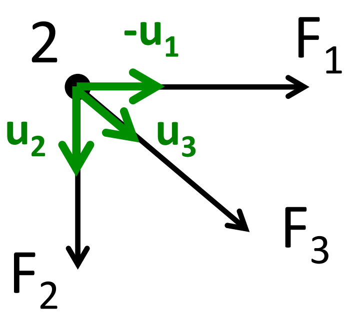
$$-F_1 - F_E = 0 \qquad \text{... (i)}$$

$$\sum F_y = 0:$$

$$-F_5 u_5 = 0$$

$$-F_5 = 0 \qquad \text{... (ii)}$$

Equilibrium of Joint 2



$$\sum F_x = 0:$$

$$-F_1 u_1 + F_3 u_{3x} = 0$$

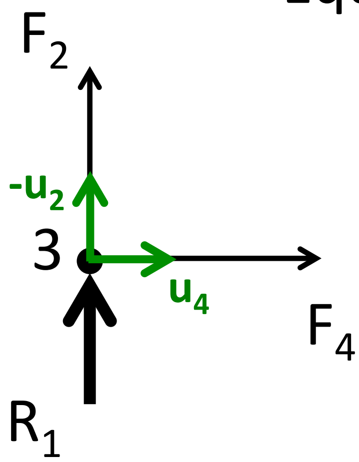
$$F_1 + \cos 45^\circ F_3 = 0 \qquad \text{... (iii)}$$

$$\sum F_y = 0:$$

$$F_2 u_2 + F_3 u_{y3} = 0$$

$$-F_2 - \sin 45^\circ F_3 = 0 \qquad \text{... (iv)}$$

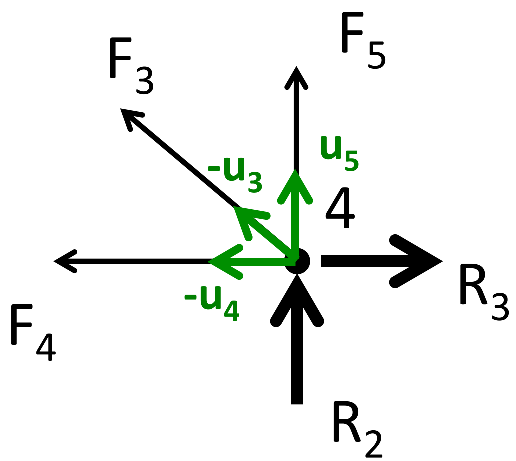
Equilibrium of Joint 3



$$\sum F_x = 0:$$
$$F_4 u_4 = 0$$
$$F_4 = 0 \quad \text{... (v)}$$

$$\sum F_y = 0:$$
$$-F_2 u_2 - R_1 u_2 = 0$$
$$F_2 + R_1 = 0 \quad \text{... (vi)}$$

Equilibrium of Joint 4



$$\sum F_x = 0:$$
$$-F_4 u_4 - F_3 u_{3x} + R_3 u_4 = 0$$
$$-F_4 - \cos 45^\circ F_3 + R_3 = 0 \quad \text{... (vii)}$$

$$\sum F_y = 0:$$
$$F_5 u_5 - F_3 u_{3y} + R_2 u_5 = 0$$
$$F_5 + \sin 45^\circ F_3 + R_2 = 0 \quad \text{... (viii)}$$

No. of equations = 2 x no. of joint … since we have 2 equations at each joint

2 x 4 = 8

$$-F_1 - F_E = 0 \quad \text{… (i)}$$

$$-F_5 = 0 \quad \text{… (ii)}$$

$$F_1 + \cos 45^\circ F_3 = 0 \quad \text{… (iii)}$$

$$-F_2 - \sin 45^\circ F_3 = 0 \quad \text{… (iv)}$$

$$F_4 = 0 \quad \text{… (v)}$$

$$F_2 + R_1 = 0 \quad \text{… (vi)}$$

$$-F_4 - \cos 45^\circ F_3 + R_3 = 0 \quad \text{… (vii)}$$

$$F_5 + \sin 45^\circ F_3 + R_2 = 0 \quad \text{… (viii)}$$

No. of unknowns = No. of members + No. of reactions

5 + 3 = 8

Solve using solve using matrices

Assemble the system of linearly independent equations

	F_1	F_2	F_3	F_4	F_5	R_1	R_2	R_3	External	Sum
Joint 1 x-dirn	$-F_1$								$-F_E$	$= 0$ … (i)
Joint 1 y-dirn					$-F_5$					$= 0$ … (ii)
Joint 2 x-dirn	F_1		$\cos 45° F_3$							$= 0$ … (iii)
Joint 2 y-dirn		$-F_2$	$-\sin 45° F_3$							$= 0$ … (iv)
Joint 3 x-dirn				F_4						$= 0$ … (v)
Joint 3 y-dirn		F_2				R_1				$= 0$ … (vi)
Joint 4 x-dirn			$-\cos 45° F_3$	$-F_4$				R_3		$= 0$ … (vii)
Joint 4 y-dirn			$\sin 45° F_3$		F_5		R_2			$= 0$ … (viii)

Assemble the system of linearly independent equations

	F_1	F_2	F_3	F_4	F_5	R_1	R_2	R_3		External
Joint 1 x-dirn	$-F_1$									$= F_E$ … (i)
Joint 1 y-dirn					$-F_5$					$= 0$ … (ii)
Joint 2 x-dirn	F_1		$\cos 45° F_3$							$= 0$ … (iii)
Joint 2 y-dirn		$-F_2$	$-\sin 45° F_3$							$= 0$ … (iv)
Joint 3 x-dirn				F_4						$= 0$ … (v)
Joint 3 y-dirn		F_2				R_1				$= 0$ … (vi)
Joint 4 x-dirn			$-\cos 45° F_3$	$-F_4$				R_3		$= 0$ … (vii)
Joint 4 y-dirn			$\sin 45° F_3$		F_5		R_2			$= 0$ … (viii)

Can write in matrix form! A x = b

Assemble the system of linearly independent equations

$$
\begin{array}{cccc}
 & \mathrm{A} & \mathrm{x} & = \quad \mathrm{b} \\
\begin{array}{c}
\text{Joint 1 x-dirn} \\ \text{Joint 1 y-dirn} \\ \text{Joint 2 x-dirn} \\ \text{Joint 2 y-dirn} \\ \text{Joint 3 x-dirn} \\ \text{Joint 3 y-dirn} \\ \text{Joint 4 x-dirn} \\ \text{Joint 4 y-dirn}
\end{array}
&
\begin{bmatrix}
-1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\
1 & 0 & \cos 45^\circ & 0 & 0 & 0 & 0 & 0 \\
0 & -1 & -\sin 45^\circ & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & -\cos 45^\circ & -1 & 0 & 0 & 0 & 1 \\
0 & 0 & \sin 45^\circ & & 1 & & 1 & 0
\end{bmatrix}
&
\begin{bmatrix}
F_1 \\ F_2 \\ F_3 \\ F_4 \\ F_5 \\ R_1 \\ R_2 \\ R_3
\end{bmatrix}
&
=
\begin{bmatrix}
F_E \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0
\end{bmatrix}
\end{array}
$$

A systematic approach

Things we need to know: (i.e. the things in the input file)

1. Location of the joint
2. Which members are connected to which joint - connectivity
3. Where are the reaction and what are there components
4. Where are the external forces and what are there components

Location of joints

Joint #	x-coordinate	y-coordinate
1	$X_1 = L$	$Y_1 = L$
2	$X_2 = 0$	$Y_2 = L$
3	$X_3 = 0$	$Y_3 = 0$
4	$X_4 = L$	$Y_4 = 0$

Connectivity

Member #	From joint	To joint
1	1	2
2	2	3
3	2	4
4	3	4
5	4	1

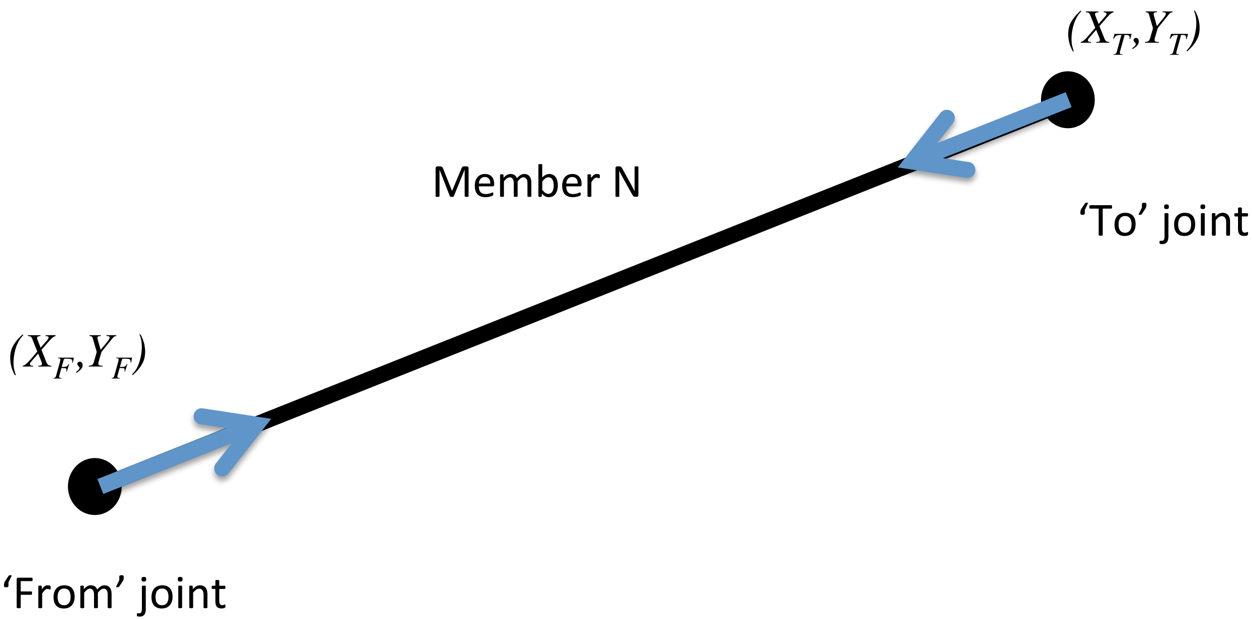
Reactions

Joint #	x-component direction	y-component direction
3	0	1
4	0	1
4	1	0

External Forces

Joint #	x-component	y-component
1	$-F_E = 1000$ N	0

Dealing with force directions – 'From' joints and 'To' joints



Unit vector for 'From' joint

$$\mathbf{u}_{\mathbf{From}} = \frac{(X_T - X_F)\,\mathbf{i} + (Y_T - Y_F)\,\mathbf{j}}{\sqrt{(X_T - X_F)^2 + (Y_T - Y_F)^2}}$$

Unit vector for 'To' joint

$$\mathbf{u}_{\mathbf{To}} = \frac{(X_F - X_T)\,\mathbf{i} + (Y_F - Y_T)\,\mathbf{j}}{\sqrt{(X_F - X_T)^2 + (Y_F - Y_T)^2}}$$

Steps to create A-matrix

Assuming that the input information in the tables have been read and stored

Enter coefficients of unknown member force first.

Start at joint 1: Means we are dealing with the 1^{st} and 2^{nd} rows of the A-matrix

Get the members that are connected to joint 1.

Members 1 and 5 are connected at joint 1.

Connectivity

Member #	From joint	To joint
1	1	2
2	2	3
3	2	4
4	3	4
5	4	1

Note whether joint is a 'From' or 'To' joint for each member

Joint 1 is a 'From' joint for member 1

Joint 1 is a 'To' joint for member 5

Note the joint that connects to the other end of each member

Member 1 is connected to joint 2

Member 5 is connected to joint 4

Form the unit vector for each member force at the joint

Steps to create A-matrix

Form the unit vector for each member force at the joint

If join is a 'From' joint use:

Unit vector for 'From' joint

$$\mathbf{u}_{\mathbf{From}} = \frac{(X_T - X_F)\,\mathbf{i} + (Y_T - Y_F)\,\mathbf{j}}{\sqrt{(X_T - X_F)^2 + (Y_T - Y_F)^2}}$$

Otherwise it is a 'To' joint, so use:

Unit vector for 'To' joint

$$\mathbf{u}_{\mathbf{To}} = \frac{(X_F - X_T)\,\mathbf{i} + (Y_F - Y_T)\,\mathbf{j}}{\sqrt{(X_F - X_T)^2 + (Y_F - Y_T)^2}}$$

Location of joints

Joint #	x-coordinate	y-coordinate
1	$\boxed{X_1 = L}$	$\boxed{Y_1 = L}$
2	$\boxed{X_2 = 0}$	$\boxed{Y_2 = L}$
3	$X_3 = 0$	$Y_3 = 0$
4	$X_4 = L$	$Y_4 = 0$

Joint 1 is a 'From' joint for member 1

$$\mathbf{u}_{1,1} = \frac{(X_2 - X_1)\,\mathbf{i} + (Y_2 - Y_1)\,\mathbf{j}}{\sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2}}$$

joint

Member

$$\mathbf{u}_{1,1} = \frac{(0 - L)\,\mathbf{i} + (L - L)\,\mathbf{j}}{\sqrt{(0 - L)^2 + (L - L)^2}}$$

$$\mathbf{u}_{1,1} = (-1)\,\mathbf{i} + (0)\,\mathbf{j}$$

Thus we can fill in the 1st and 2nd row entries in the A-matrix for the F_1 column

i.e. Row 1 - Joint 1 x-direction
Column 1 - force F_1 column
Coefficient = -1

i.e. Row 2 - Joint 1 y-direction
Column 1 - force F_1 column
Coefficient = 0

Steps to create A-matrix

Joint 1 is a 'To' joint for member 5

$$\mathbf{u}_{1,5} = \frac{(X_4 - X_1)\,\mathbf{i} + (Y_4 - Y_1)\,\mathbf{j}}{\sqrt{(X_4 - X_1)^2 + (Y_4 - Y_1)^2}}$$

$$\mathbf{u}_{1,5} = \frac{(L - L)\,\mathbf{i} + (0 - L)\,\mathbf{j}}{\sqrt{(L - L)^2 + (0 - L)^2}}$$

$$\mathbf{u}_{1,5} = (0)\,\mathbf{i} + (-1)\,\mathbf{j}$$

Thus we can fill in the 1st and 2nd row entries in the A-matrix for the F_5 column

i.e. Row 1 - Joint 1 x-direction
Column 5 - force F_5 column
Coefficient = 0

i.e. Row 2 - Joint 1 y-direction
Column 5 - force F_5 column
Coefficient = 1

Location of joints

Joint #	x-coordinate	y-coordinate
1	$\boxed{X_1 = L}$	$\boxed{Y_1 = L}$
2	$X_2 = 0$	$Y_2 = L$
3	$X_3 = 0$	$Y_3 = 0$
4	$\boxed{X_4 = L}$	$\boxed{Y_4 = 0}$

Steps to create A-matrix

Next, move to joint 2

At joint 2: Means we are dealing with the 3rd and 4th rows of the A-matrix

Get the members that are connected to joint 2.

Members 1, 2, and 3 are connected at joint 2.

Note whether joint is a 'From' or 'To' joint for each member

Joint 2 is a 'To' joint for member 1

Joint 2 is a 'From' joint for member 2

Joint 2 is a 'From' joint for member 3

Note the joint that connects to the other end of each member

Member 1 is connected to joint 1

Member 2 is connected to joint 3

Member 3 is connected to joint 4

Form the unit vector for each member force at the joint

Connectivity

Member #	From joint	To joint
1	1	2
2	2	3
3	2	4
4	3	4
5	4	1

Steps to create A-matrix

Form the unit vector for each member force at the joint

If join is a 'From' joint use:

Unit vector for 'From' joint

$$\mathbf{u}_{\mathbf{From}} = \frac{(X_T - X_F)\,\mathbf{i} + (Y_T - Y_F)\,\mathbf{j}}{\sqrt{(X_T - X_F)^2 + (Y_T - Y_F)^2}}$$

Otherwise it is a 'To' joint, so use:

Unit vector for 'To' joint

$$\mathbf{u}_{\mathbf{To}} = \frac{(X_F - X_T)\,\mathbf{i} + (Y_F - Y_T)\,\mathbf{j}}{\sqrt{(X_F - X_T)^2 + (Y_F - Y_T)^2}}$$

Location of joints

Joint #	x-coordinate	y-coordinate
1	$\boxed{X_1 = L}$	$\boxed{Y_1 = L}$
2	$\boxed{X_2 = 0}$	$\boxed{Y_2 = L}$
3	$X_3 = 0$	$Y_3 = 0$
4	$X_4 = L$	$Y_4 = 0$

Joint 2 is a 'To' joint for member 1

$$\mathbf{u}_{2,1} = \frac{(X_1 - X_2)\,\mathbf{i} + (Y_1 - Y_2)\,\mathbf{j}}{\sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2}}$$

$$\mathbf{u}_{2,1} = \frac{(L - 0)\,\mathbf{i} + (L - L)\,\mathbf{j}}{\sqrt{(L-0)^2 + (L-L)^2}}$$

$$\mathbf{u}_{2,1} = (1)\,\mathbf{i} + (0)\,\mathbf{j}$$

Thus we can fill in the 3rd and 4th row entries in the A-matrix for the F_1 column

i.e. Row 3 – Joint 2 x-direction
Column 1 - force F_1 column
Coefficient = 1

i.e. Row 4 – Joint 2 y-direction
Column 1 - force F_1 column
Coefficient = 0

Steps to create A-matrix

Joint 2 is a 'From' joint for member 2

$$\mathbf{u_{2,2}} = \frac{(X_3 - X_2)\,\mathbf{i} + (Y_3 - Y_2)\,\mathbf{j}}{\sqrt{(X_3 - X_2)^2 + (Y_3 - Y_2)^2}}$$

$$\mathbf{u_{2,2}} = \frac{(0 - 0)\,\mathbf{i} + (0 - L)\,\mathbf{j}}{\sqrt{(0 - 0)^2 + (0 - L)^2}}$$

$$\mathbf{u_{2,2}} = (0)\,\mathbf{i} + (-1)\,\mathbf{j}$$

Thus we can fill in the 3rd and 4th row entries in the A-matrix for the F_2 column

i.e. Row 3 – Joint 2 x-direction
Column 2 - force F_2 column
Coefficient = 0

i.e. Row 4 – Joint 2 y-direction
Column 2 - force F_2 column
Coefficient = -1

Location of joints

Joint #	x-coordinate	y-coordinate
1	$X_1 = L$	$Y_1 = L$
2	$\boxed{X_2 = 0}$	$\boxed{Y_2 = L}$
3	$\boxed{X_3 = 0}$	$\boxed{Y_3 = 0}$
4	$X_4 = L$	$Y_4 = 0$

Steps to create A-matrix

Joint 2 is a 'From' joint for member 3

$$\mathbf{u}_{2,3} = \frac{(X_4 - X_2)\,\mathbf{i} + (Y_4 - Y_2)\,\mathbf{j}}{\sqrt{(X_4 - X_2)^2 + (Y_4 - Y_2)^2}}$$

$$\mathbf{u}_{2,3} = \frac{(L - 0)\,\mathbf{i} + (0 - L)\,\mathbf{j}}{\sqrt{(L - 0)^2 + (0 - L)^2}}$$

$$\mathbf{u}_{2,3} = (1/\sqrt{2}\,)\,\mathbf{i} + (-1/\sqrt{2})\,\mathbf{j}$$

Thus we can fill in the 3rd and 4th row entries in the A-matrix for the F_3 column

i.e. Row 3 – Joint 2 x-direction
Column 3 - force F_3 column
Coefficient = 1/√2

i.e. Row 4 – Joint 2 y-direction
Column 3 - force F_3 column
Coefficient = -1/√2

Location of joints

Joint #	x-coordinate	y-coordinate
1	$X_1 = L$	$Y_1 = L$
2	$\boxed{X_2 = 0}$	$\boxed{Y_2 = L}$
3	$X_3 = 0$	$Y_3 = 0$
4	$\boxed{X_4 = L}$	$\boxed{Y_4 = 0}$

Steps to create A-matrix

Next, move to joint 3

At joint 3: Means we are dealing with the 5^{th} and 6^{th} rows of the A-matrix

Get the members that are connected to joint 3.

Members 2, and 4 are connected at joint 3.

Note whether joint is a 'From' or 'To' joint for each member

Joint 3 is a 'To' joint for member 2

Joint 3 is a 'From' joint for member 4

Note the joint that connects to the other end of each member

Member 2 is connected to joint 2

Member 4 is connected to joint 4

Form the unit vector for each member force at the joint

Connectivity

Member #	From joint	To joint
1	1	2
2	2	3
3	2	4
4	3	4
5	4	1

Steps to create A-matrix

Form the unit vector for each member force at the joint

If join is a 'From' joint use:

Unit vector for 'From' joint

$$\mathbf{u}_{\mathbf{From}} = \frac{(X_T - X_F)\,\mathbf{i} + (Y_T - Y_F)\,\mathbf{j}}{\sqrt{(X_T - X_F)^2 + (Y_T - Y_F)^2}}$$

Otherwise it is a 'To' joint, so use:

Unit vector for 'To' joint

$$\mathbf{u}_{\mathbf{To}} = \frac{(X_F - X_T)\,\mathbf{i} + (Y_F - Y_T)\,\mathbf{j}}{\sqrt{(X_F - X_T)^2 + (Y_F - Y_T)^2}}$$

Location of joints

Joint #	x-coordinate	y-coordinate
1	$X_1 = L$	$Y_1 = L$
2	$\boxed{X_2 = 0}$	$\boxed{Y_2 = L}$
3	$\boxed{X_3 = 0}$	$\boxed{Y_3 = 0}$
4	$X_4 = L$	$Y_4 = 0$

Joint 3 is a 'To' joint for member 2

$$\mathbf{u}_{3,2} = \frac{(X_2 - X_3)\,\mathbf{i} + (Y_2 - Y_3)\,\mathbf{j}}{\sqrt{(X_2 - X_3)^2 + (Y_2 - Y_3)^2}}$$

$$\mathbf{u}_{3,2} = \frac{(0 - 0)\,\mathbf{i} + (L - 0)\,\mathbf{j}}{\sqrt{(0 - 0)^2 + (L - 0)^2}}$$

$$\mathbf{u}_{3,2} = (0)\,\mathbf{i} + (1)\,\mathbf{j}$$

Thus we can fill in the 5th and 6th row entries in the A-matrix for the F_2 column

i.e. Row 5 – Joint 3 x-direction
Column 2 - force F_2 column
Coefficient = 0

i.e. Row 6 – Joint 3 y-direction
Column 2 - force F_2 column
Coefficient = 1

Steps to create A-matrix

Joint 3 is a 'From' joint for member 4

$$\mathbf{u}_{3,4} = \frac{(X_4 - X_3)\,\mathbf{i} + (Y_4 - Y_3)\,\mathbf{j}}{\sqrt{(X_4 - X_3)^2 + (Y_4 - Y_3)^2}}$$

$$\mathbf{u}_{3,4} = \frac{(L - 0)\,\mathbf{i} + (0 - 0)\,\mathbf{j}}{\sqrt{(L - 0)^2 + (0 - 0)^2}}$$

$$\mathbf{u}_{3,4} = (1)\,\mathbf{i} + (0)\,\mathbf{j}$$

Thus we can fill in the 5th and 6th row entries in the A-matrix for the F_4 column

i.e. Row 5 – Joint 3 x-direction
Column 4 - force F_4 column
Coefficient = 1

i.e. Row 6 – Joint 3 y-direction
Column 4 - force F_4 column
Coefficient = 0

Location of joints

Joint #	x-coordinate	y-coordinate
1	$X_1 = L$	$Y_1 = L$
2	$X_2 = 0$	$Y_2 = L$
3	$\boxed{X_3 = 0}$	$\boxed{Y_3 = 0}$
4	$\boxed{X_4 = L}$	$\boxed{Y_4 = 0}$

Steps to create A-matrix

Next, move to joint 4

At joint 4: Means we are dealing with the 7th and 8th rows of the A-matrix

Get the members that are connected to joint 4.

Members 3, 4, and 5 are connected at joint 4.

Note whether joint is a ‘From’ or ‘To’ joint for each member

Joint 4 is a ‘To’ joint for member 3

Joint 4 is a ‘To’ joint for member 4

Joint 4 is a ‘From’ joint for member 5

Note the joint that connects to the other end of each member

Member 3 is connected to joint 2

Member 4 is connected to joint 3

Member 5 is connected to joint 1

Form the unit vector for each member force at the joint

Connectivity

Member #	From joint	To joint
1	1	2
2	2	3
3	2	4
4	3	4
5	4	1

Steps to create A-matrix

Form the unit vector for each member force at the joint

If join is a 'From' joint use:

Unit vector for 'From' joint

$$\mathbf{u}_{\mathbf{From}} = \frac{(X_T - X_F)\,\mathbf{i} + (Y_T - Y_F)\,\mathbf{j}}{\sqrt{(X_T - X_F)^2 + (Y_T - Y_F)^2}}$$

Otherwise it is a 'To' joint, so use:

Unit vector for 'To' joint

$$\mathbf{u}_{\mathbf{To}} = \frac{(X_F - X_T)\,\mathbf{i} + (Y_F - Y_T)\,\mathbf{j}}{\sqrt{(X_F - X_T)^2 + (Y_F - Y_T)^2}}$$

Location of joints

Joint #	x-coordinate	y-coordinate
1	$X_1 = L$	$Y_1 = L$
2	$\boxed{X_2 = 0}$	$\boxed{Y_2 = L}$
3	$X_3 = 0$	$Y_3 = 0$
4	$\boxed{X_4 = L}$	$\boxed{Y_4 = 0}$

Joint 4 is a 'To' joint for member 3

$$\mathbf{u}_{4,3} = \frac{(X_2 - X_4)\,\mathbf{i} + (Y_2 - Y_4)\,\mathbf{j}}{\sqrt{(X_2 - X_4)^2 + (Y_2 - Y_4)^2}}$$

$$\mathbf{u}_{4,3} = \frac{(0 - L)\,\mathbf{i} + (L - 0)\,\mathbf{j}}{\sqrt{(L-0)^2 + (L-L)^2}}$$

$$\mathbf{u}_{4,3} = (-1/\sqrt{2})\,\mathbf{i} + (1/\sqrt{2})\,\mathbf{j}$$

Thus we can fill in the 7th and 8th row entries in the A-matrix for the F_3 column

i.e. Row 7 – Joint 4 x-direction
Column 3 - force F_3 column
Coefficient = $-1/\sqrt{2}$

i.e. Row 8 – Joint 4 y-direction
Column 3 - force F_3 column
Coefficient = $1/\sqrt{2}$

Steps to create A-matrix

Joint 4 is a 'To' joint for member 4

$$\mathbf{u}_{4,4} = \frac{(X_3 - X_4)\,\mathbf{i} + (Y_3 - Y_4)\,\mathbf{j}}{\sqrt{(X_3 - X_4)^2 + (Y_3 - Y_4)^2}}$$

$$\mathbf{u}_{4,4} = \frac{(0 - L)\,\mathbf{i} + (0 - 0)\,\mathbf{j}}{\sqrt{(0 - L)^2 + (0 - 0)^2}}$$

$$\mathbf{u}_{4,4} = (-1)\,\mathbf{i} + (0)\,\mathbf{j}$$

Thus we can fill in the 7th and 8th row entries in the A-matrix for the F_4 column

i.e. Row 7 – Joint 4 x-direction
Column 4 - force F_4 column
Coefficient = -1

i.e. Row 8 – Joint 4 y-direction
Column 4 - force F_4 column
Coefficient = 0

Location of joints

Joint #	x-coordinate	y-coordinate
1	$X_1 = L$	$Y_1 = L$
2	$X_2 = 0$	$Y_2 = L$
3	$\boxed{X_3 = 0}$	$\boxed{Y_3 = 0}$
4	$\boxed{X_4 = L}$	$\boxed{Y_4 = 0}$

Steps to create A-matrix

Joint 4 is a 'From' joint for member 5

$$\mathbf{u_{4,5}} = \frac{(X_1 - X_4)\,\mathbf{i} + (Y_1 - Y_4)\,\mathbf{j}}{\sqrt{(X_1 - X_4)^2 + (Y_1 - Y_4)^2}}$$

$$\mathbf{u_{4,5}} = \frac{(L - L)\,\mathbf{i} + (L - 0)\,\mathbf{j}}{\sqrt{(L - L)^2 + (L - 0)^2}}$$

$$\mathbf{u_{4,5}} = (0)\,\mathbf{i} + (1)\,\mathbf{j}$$

Thus we can fill in the 7th and 8th row entries in the A-matrix for the F_5 column

i.e. Row 7 – Joint 4 x-direction
Column 5 - force F_5 column
Coefficient = 0

i.e. Row 4 – Joint 2 y-direction
Column 5 - force F_5 column
Coefficient = 1

Location of joints

Joint #	x-coordinate	y-coordinate
1	$\boxed{X_1 = L}$	$\boxed{Y_1 = L}$
2	$X_2 = 0$	$Y_2 = L$
3	$X_3 = 0$	$Y_3 = 0$
4	$\boxed{X_4 = L}$	$\boxed{Y_4 = 0}$

Steps to create A-matrix

Next, enter coefficients for the reactions

Reaction 1 is at joint 3: Means we are dealing with the 5th and 6th rows of the A-matrix

We are dealing with the R_1 column, i.e. column 6

We can fill in the 5th and 6th row entries in the A-matrix for the R_1 column

i.e. Row 5 – Joint 3 x-direction

Column 6 – force R_1 column

Coefficient = 0

i.e. Row 6 – Joint 3 y-direction

Column 6 – force R_1 column

Coefficient = 1

Reactions

Joint #	x-component direction	y-component direction
3	0	1
4	0	1
4	1	0

Steps to create A-matrix

Reaction 2 is at joint 4: Means we are dealing with the 7^{th} and 8^{th} rows of the A-matrix

We are dealing with the R_2 column, i.e. column 7

We can fill in the 7^{th} and 8^{th} row entries in the A-matrix for the R_2 column

i.e. Row 7 – Joint 4 x-direction

Column 7 – force R_1 column

Coefficient = 0

i.e. Row 8 – Joint 4 y-direction

Column 7 – force R_1 column

Coefficient = 1

Reactions

Joint #	x-component direction	y-component direction
3	0	1
4	$\boxed{0}$	$\boxed{1}$
4	1	0

Steps to create A-matrix

Reaction 3 is at joint 4: Means we are dealing with the 7th and 8th rows of the A-matrix

We are dealing with the R_3 column, i.e. column 8

We can fill in the 7th and 8th row entries in the A-matrix for the R_2 column

i.e. Row 7 – Joint 4 x-direction

Column 8 – force R_3 column

Coefficient = 1

i.e. Row 8 – Joint 4 y-direction

Column 8 – force R_3 column

Coefficient = 0

Reactions

Joint #	x-component direction	y-component direction
3	0	1
4	0	1
4	$\boxed{1}$	$\boxed{0}$

Steps to create b-matrix

Enter the know external forces

External Force is at joint 1: Means we are dealing with the 1st and 2nd rows of the b-matrix

We can fill in the 1st and 2nd row entries in the b-matrix:

i.e. Row 1 – Joint 1 x-direction

Value = -1000

i.e. Row 2 – Joint 1 y-direction

Value = 0

External Forces

Joint #	x-component	y-component
1	$\boxed{-F_E = -1000\text{ N}}$	$\boxed{0}$