Activity 2.1.6 Step-by-Step Truss System Answer Key

Introduction

Truss systems are essential components within structural systems ranging from residential construction to large scale civil engineering projects such as bridges. Regardless of the system application, trusses are designed to utilize material strength, reduce costs, and support a determined load. Engineers must be able to understand how loads act on a truss structure and within the structure to ensure design feasibility and safety. Activity 3.1.7 will guide you through the step-by-step process of calculating reaction forces and member forces within a truss system.

Equipment

* Straight edge
* Calculator
* Pencil

Procedure

In this activity you will calculate reaction and member forces for the truss system illustrated below. It is essential to follow each step within the procedure to ensure proper calculations and free body diagrams.

Calculate External Reaction Forces
x and y Reaction Force at Pin A and y Reaction Force at Roller C

1. Draw a freebody diagram for the entire truss structure illustrated above.
Make sure to include all known and unknown angles, forces, and distances.Calculate and determine all angles using trigonometry and geometry.

(1 Box = .5 Units)

|  |  |
| --- | --- |
|  | Algebra help hints: sin θ = O/H cos θ = A/Htan θ = O/Aa2 + b2 = c2 |

1. Calculate reaction forces at the roller and pin connections.
	1. List static equilibrium equations – Hint: They all involve summations.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ΣFx=0 |  | ΣFy=0 |  | ΣM=0 |

* 1. List all know and unknown forces acting and reacting on the truss structure Label direction of force with an arrow.
		1. Forces in the x-direction

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | RAx→ |  |  |  |

* + 1. Forces in the y-direction

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | RAy↑ |  | RCy↑ |  | 1000lb↓ |  | 500lb↓ |  | 250lb↓ |

* + 1. Moment Forces – Determined from Pin A

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Formula review: M = Fd |  |  | 1000 x 3  |  | 250 x 5 |  | 500 x 7 |  | RFCy x 10 |

* 1. Solve for RCY by using the moment static equilibrium equation acting upon pin A.

|  |  |  |
| --- | --- | --- |
| ΣM=0 |  | -3000 - 1250 - 3500 + (10RCy)= 0 |
| Equation |  | Substitution |

|  |  |  |  |
| --- | --- | --- | --- |
| 10RCy = 7750 |  | RCy= 775 lb*Note: The answer is positive, so the assumed direction is correct.* |  |
| Simplification |  | Solution |

* 1. Solve for unknown reaction force in the x-direction (RAx).
	Use the sum of forces in the x-direction equilibrium equation.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | ΣFx=0 |  | RAx=0 |  | RAx= 0 |
|  | Equation |  | Substitution |  | Solution |

* 1. Solve for unknown reaction forces in the y-direction.
	Use the sum of forces in the y-direction equilibrium equation.

|  |  |  |
| --- | --- | --- |
| ΣFy=0 |  | RAy + RCy +(-1000lb) + (-500lb) + (-250lb) = 0 |
| Equation |  | Substitution |

|  |  |  |
| --- | --- | --- |
|  |  | RAy + 775lb = 1750lbRAy = 975lb |
|  |  | Solution |  |

* 1. Draw a freebody diagram for the entire truss system illustrated on page 1.
	Make sure to include your calculated support reactions (1 Box = .5 Units).

|  |
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|  |

Calculate Individual Truss Member Forces

1. Calculate member forces AD and AB
	1. Draw the freebody diagram for joint A.

Make sure to include all known and unknown angles and forces (including x and y vector components). Do not include lengths.

|  |  |
| --- | --- |
|  | Updated Drawing  |

* 1. Use SOH CAH TOA to express ADX and ADY in terms of AD.
		1. Calculate ADX

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | ADX = ADsin45° |
| Equation |  | Substitution |  | Solution |

* + 1. Calculate ADY

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | ADY = ADcos45° |
| Equation |  | Substitution |  | Solution |

* 1. List all know and unknown forces.
	Label direction of force with an arrow.
		1. Forces in the x-direction

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| RAx = 0lb → |  | AB → |  | (ADsin45°) → |

* + 1. Forces in the y-direction

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | 975 lb ↑ |  | (ADcos45°) ↑ |

* 1. Use static equilibrium equations to solve for AD and AB.
		1. Solve for AD by calculating y-direction static equilibrium.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ΣFy=0 |  | 975 lb + (AD x cos45°) |  | AD x cos45° = -975 lb |
| Equation |  | Substitution |  | Simplification |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | AD = -1378.86 lb*Note: The answer is negative, so change the assumed direction.* |
|  |  | Simplification |  | Solution |

* + 1. Solve for AB by calculating x-direction static equilibrium.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ΣFx=0 |  | RAx + AB + (ADsin45o) = 00 lb + AB + (AD x Sin45°) = 0 |  | AD x Sin45° = -AB |
| Equation |  | Substitution |  | Simplification |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | -1378.86 lb x sin45° = -AB |  | AB = 975 lbAB is under tension |
|  |  | Substitution – Insert calculated FAD value |  | Solution |

* 1. Update the joint A freebody diagram with calculated forces for AD and AB.
1. Calculate CB and CE.
	1. Draw the freebody diagram for jointC.

Make sure to include all known and unknown angles and forces (including x and y vector components). Do not include lengths.

|  |  |
| --- | --- |
|  | Updated Drawing  |

* 1. Use SOH CAH TOA to express CEx and CEy in terms of CE.
		1. Calculate CEx

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | CEx = CEsin45° |
| Equation |  | Substitution |  | Solution |

* + 1. Calculate FCEY

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | CEy = CEcos45° |
| Equation |  | Substitution |  | Solution |

* 1. List all know and unknown forces.
	Label direction of force with an arrow.
		1. Forces in the x-direction

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | **CB** ← |  | **CEsin45°**← |

* + 1. Forces in the y-direction

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | 775 lb ↑ |  | CEcos45° ↑ |

* 1. Use static equilibrium equations to solve for AD and AB.
		1. Solve for CE by calculating y-direction static equilibrium.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ΣFy=0 |  | 775 lb + (CEcos45°) = 0 |  | CEcos45° = -775 lb |
| Equation |  | Substitution |  | Simplification |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | CE = -1096.02 lb*Note: The answer is negative, so change the assumed direction.* |
|  |  |  |  | Solution |

* + 1. Solve for CB by calculating x-direction static equilibrium.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ΣFx=0 |  | CB + (CEsin45°) = 0 |  | -CB = CESin45° |
| Equation |  | Substitution |  | Simplification |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | -CB = -1096.02 lb Sin45°  |  | CB = 775 lb |
|  |  | Substitution – Insert calculated CE value |  | Solution |

* 1. Update joint C free-body diagram with calculated forces for CE and CB.
1. Calculate EB and ED
	1. Draw the free-body diagram for jointE.

Make sure to include all known and unknown angles and forces (including x and y vector components). Do not include lengths.

|  |  |
| --- | --- |
|  | Updated Drawing  |

* 1. Use SOH CAH TOA to express EBx and EBy in terms of EB.
		1. Calculate EBy

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | EBy = EB sin56° |
| Equation |  | Substitution |  | Solution |

* + 1. Calculate FEBX

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | EBx = EB cos56° |
| Equation |  | Substitution |  | Solution |

* 1. List all know and unknown forces.
	Label direction of force with an arrow.
		1. Forces in the x-direction

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ED ← |  | 775 lb ← |  | EBcos56° ← |

* + 1. Forces in the y-direction

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 500 lb↓ |  | 775 lb↑ |  | EB sin56° ↓ |

* 1. Use static equilibrium equations to solve for EB.
		1. Calculate y-direction static equilibrium.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ΣFy=0 |  | -500lb + 775 lb + (-EB sin56°) = 0 |  | 275lb - EB sin56° = 0 |
| Equation |  | Substitution |  | Simplification |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| -EB sin56° = -275 lb |  |  |  | EB = 331.71 lb |
| Substitution |  | Simplification |  | Solution |

* + 1. Calculate x-direction static equilibrium.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ΣFX=0 |  | -ED - 775lb - (EB cos56°)=0 |  | -ED - (331.71 cos56°) = 775 |
| Equation |  | Substitution |  | Simplification |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| -ED - (185.27lb) = 775lb |  | -ED = 185.27lb + 775lb |  | ED = -960.27lb*Note: The answer is negative, so change the assumed direction.* |
| Substitution |  | Simplification |  | Solution |

* 1. Update joint E freebody diagram with calculated forces for EB and ED.
1. Calculate DB
	1. Draw the freebody diagram for jointD.

Make sure to include all known and unknown angles and forces (including x and y vector components). Do not include lengths.

|  |  |
| --- | --- |
|  | Updated Drawing  |

* 1. Use SOH CAH TOA to express DBx and DBy in terms of DB.
		1. Calculate DBy

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | DBY = DB sin56° |
| Equation |  | Substitution |  | Solution |

* + 1. Calculate FDBX

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | DBX = DB cos56° |
| Equation |  | Substitution |  | Solution |

* 1. List all know and unknown forces.
	Label direction of force with an arrow.
		1. Forces in the x-direction

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 975 lb→ |  | 960.27 lb ← |  |  DB cos56°→ |

* + 1. Forces in the y-direction

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  975 lb ↑ |  | 1000 lb ↓ |  | DB sin56°↓  |

* 1. Use static equilibrium equations to solve for DB.
		1. Solve for DB by Calculatingy-direction static equilibrium.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ΣFy=0 |  | 975lb + (-1000lb) - (DB sin56°)=0 |  | -25lb = DB sin56° |
| Equation |  | Substitution |  | Simplification |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | DB = -30.05 lb |
|  |  | Simplification |  | Solution |

* 1. Update joint D freebody diagram with calculated forces for DB and DE.

Draw Completed Free Body Diagram

1. Draw a completed freebody diagram for entire truss structure using all calculated reaction and member forces.

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