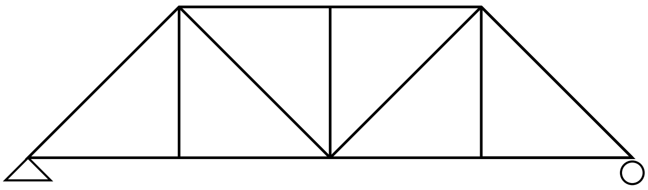
Project #1 - Modeling a Truss

Maggie Anthes & William Goldman

10/19/25

Part 1: Design a truss and find support reactions

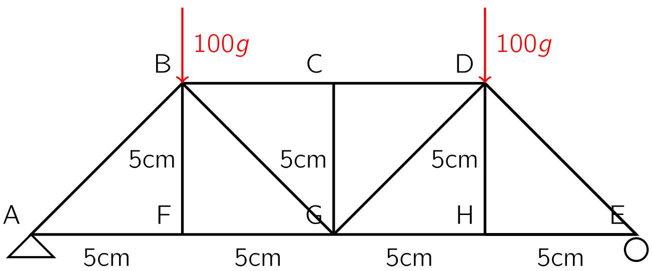
Statistically Determinate



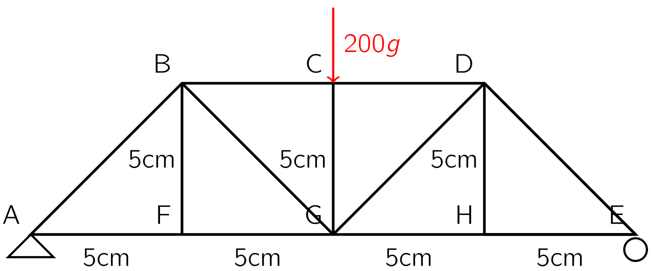
Our selected truss, a Hip truss

The Hip truss is statistically determinate. It satisfies the given equation, $2M = N + R$ where M is the number of joint, N is the number of bars, and R is the number of support reactions. For the truss depicted above, there are 8 joints, 13 members, and three support reactions from the roller support and the pin support. Thus $M = 8, N = 13, R = 3$. Plugging in to the equation gives $2(8) = 13 + 3 \rightarrow 16 = 16!$

Loading Conditions

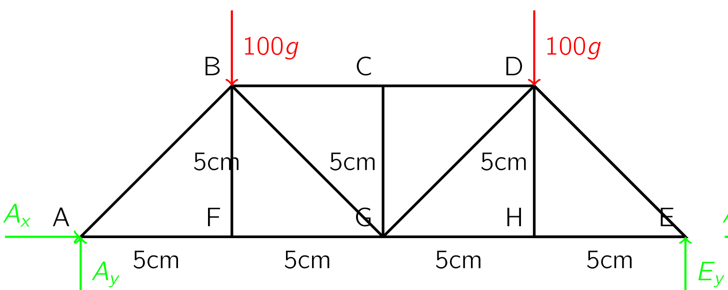


Loading Condition 1

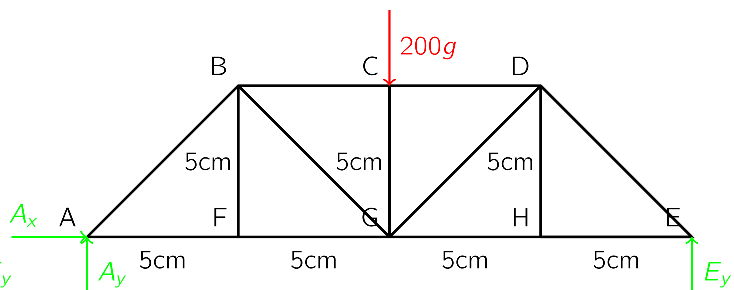


Loading Condition 2

Free Body Diagrams



Free-Body Diagram 1



Free-Body Diagram 2

Calculations

Loading Condition 1

Equilibrium Equations

$$100\text{g} = 0.98\text{N}, \quad 5\text{cm} = 0.05\text{m}$$

$$\Sigma F_x = \boxed{0 = A_x}$$

$$\Sigma F_y = 0 = A_y + E_y - 0.98\text{N} - 0.98\text{N}$$

$$\Sigma M_A = 0 = E_y(0.2\text{m}) - 0.98\text{N}(0.05\text{m} + 0.15\text{m})$$

Moment Equation

$$E_y(0.2) = 0.98(0.05) + 0.98(0.15)$$

$$E_y(0.2) = 0.196$$

$$\boxed{E_y = 0.98\text{N}}$$

Y-Direction Equilibrium

$$A_y = 0.98\text{N} + 0.98\text{N} - E_y$$

$$A_y = 0.98\text{N} + 0.98\text{N} - 0.98\text{N}$$

$$\boxed{A_y = 0.98\text{N}}$$

Support Reactions

$$A_x = 0\text{N}, \quad A_y = 0.98\text{N}, \quad E_y = 0.98\text{N}$$

Loading Condition 2

Equilibrium Equations

$$200\text{g} = 1.96\text{N}, \quad 5\text{cm} = 0.05\text{m}$$

$$\Sigma F_x = \boxed{0 = A_x}$$

$$\Sigma F_y = 0 = A_y + E_y - 1.96\text{N}$$

$$\Sigma M_A = 0 = E_y(0.2\text{m}) - 1.96\text{N}(0.1\text{m})$$

Moment Equation

$$E_y(0.2\text{m}) = 1.96\text{N}(0.1\text{m})$$

$$E_y(0.2\text{m}) = 0.196\text{N}$$

$$\boxed{E_y = 0.98\text{N}}$$

Y-Direction Equilibrium

$$A_y = 1.96\text{N} - E_y$$

$$A_y = 1.96\text{N} - 0.98\text{N}$$

$$\boxed{A_y = 0.98\text{N}}$$

Support Reactions

$$A_x = 0\,\text{N}, \quad A_y = 0.98\text{N}, \quad E_y = 0.98\text{N}$$

Part 2: Build the truss and find support reactions

Building Process

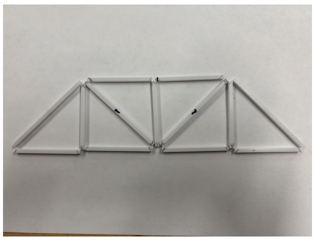


Figure 1: All beams are cut (5cm and 7cm sections)

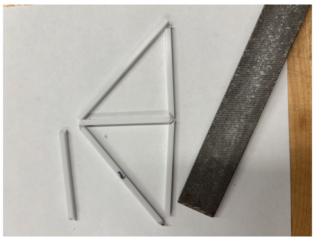


Figure 2: Joints are filed to create angles

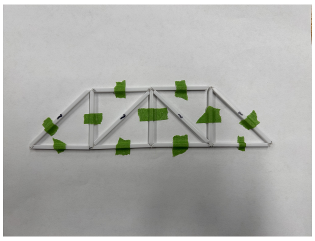


Figure 3: Filed beams are taped in place

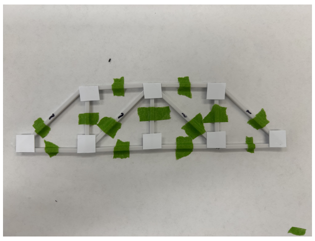


Figure 4: Gussets are glued to join the members

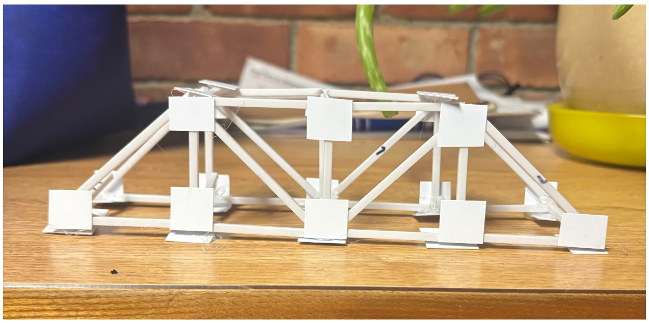


Figure 5: Final Truss

Testing

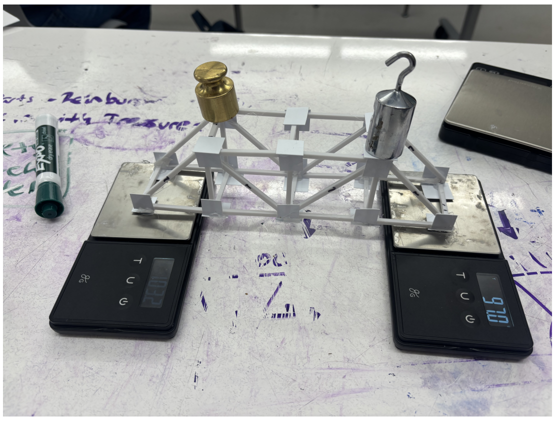


Figure 6: Physical Loading Condition 1

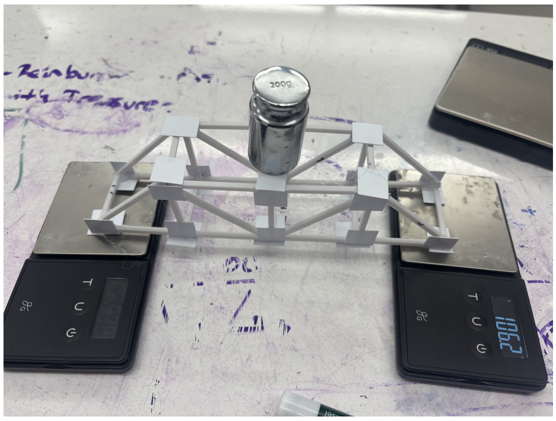


Figure 7: Physical Loading Condition 2

Note: Asymmetry occurred when we constructed the 3-dimensional truss, causing slight wobbling when loading conditions were applied. This is reflected in the uneven loading found on each support. Each 2-dimensional truss was constructed to satisfaction, but error occurred when securing the cross beams. We can assume that a more uniform construction would result in symmetric loading as predicted in calculations and the truss calculator.

Measured support reactions for both loading conditions:

Loading Condition 1 — Support Reactions

$A_x = 0\,\text{N}$

$A_y = 103.2\,\text{g} = 0.1032\,\text{kg}$

$A_y = 0.1032(9.8) = 1.01136\,\text{N}$

$E_y = 97\,\text{g} = 0.097\,\text{kg}$

$E_y = 0.097(9.8) = 0.9506\,\text{N}$

$\boxed{A_y = 1.01136\,\text{N},\ E_y = 0.9506\,\text{N}}$

Loading Condition 2 — Support Reactions

$A_x = 0\,\text{N}$

$A_y = 106.2\,\text{g} = 0.1062\,\text{kg}$

$A_y = 0.1062(9.8) = 1.04076\,\text{N}$

$E_y = 93.8\,\text{g} = 0.0938\,\text{kg}$

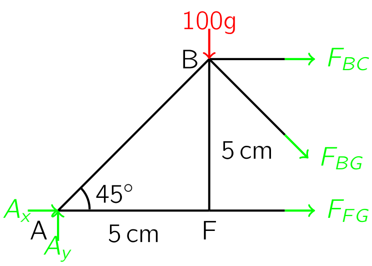
$E_y = 0.0938(9.8) = 0.91924\,\text{N}$

$\boxed{A_y = 1.04076\,\text{N},\ E_y = 0.91924\,\text{N}}$

Part 3: Calculate the members' internal loads (theoretical calculations)

Loading Condition 1

Section ABF



Section ABF — Calculations

Equilibrium:

$$\Sigma F_x = 0 = A_x + F_{FG} + F_{BC} + F_{BG}\sin 45^\circ$$
$$\Sigma F_y = 0 = -0.98N - F_{BG}\sin 45^\circ + A_y$$
$$\Sigma M_B = 0 = A_x(0.05\text{m}) + F_{FG}(0.05\text{m}) - A_y(0.05\text{m})$$

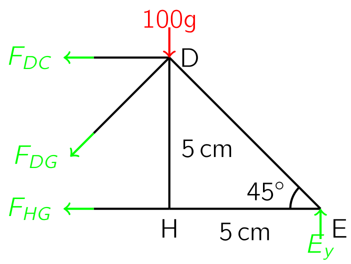
Solve (use $A_y = 0.98$ N and $A_x = 0$):

$$0 = 0(0.05\text{m}) + F_{FG}(0.05\text{m}) - 0.98\text{N}(0.05\text{m}) \Rightarrow \boxed{F_{FG} = 0.98N\ (T)}$$

$$0 = -0.98N - F_{BG}\sin 45^\circ + 0.98\text{N} \Rightarrow \boxed{F_{BG} = 0}$$

$$0 = 0 + 0.98\text{N} + F_{BC} + 0 \Rightarrow \boxed{F_{BC} = -0.98\text{N}\ (C)}$$

Section DHE



Section DHE — Calculations

Equilibrium:

$$\Sigma F_x = 0 = -F_{DC} - F_{HG} - F_{DG}\sin 45°$$
$$\Sigma F_y = 0 = -0.98N - F_{DG}\sin 45° + E_y$$
$$\Sigma M_D = 0 = E_y(0.05\text{m}) - F_{HG}(0.05\text{m})$$

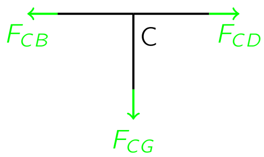
Solve (use $E_y = 0.98$ N):

$$0 = 0.98\text{N}(0.05\text{m}) - F_{HG}(0.05\text{m}) \Rightarrow \boxed{F_{HG} = 0.98N\ (T)}$$

$$0 = -0.98N - F_{DG}\sin 45° + 0.98\text{N} \Rightarrow \boxed{F_{DG} = 0}$$

$$0 = -F_{CD} - 0.98\text{N} - 0 \Rightarrow \boxed{F_{DC} = -0.98\text{N}\ (C)}$$

Joint C



Joint C — Calculations

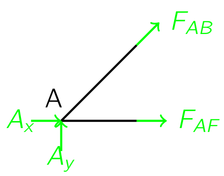
Equilibrium:

$$\Sigma F_x = 0 = F_{CD} - F_{CB}$$
$$\Sigma F_y = 0 = F_{CG}$$

Solve (use $F_{CD} = 0.98$N and $F_{CB} = -0.98$N):

$$\boxed{F_{CG} = 0\text{N}}$$

Joint A



Joint A — Calculations

Equilibrium:

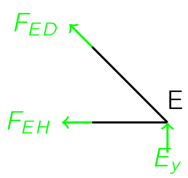
$$\Sigma F_x = 0 = A_x + F_{AF} + F_{AB}\sin 45°$$
$$\Sigma F_y = 0 = A_y + F_{AB}\sin 45°$$

Solve (use $A_y = 0.98$N and $A_x = 0$N):

$$0 = 0.98\text{N} + F_{AB}\sin 45° \Rightarrow \boxed{F_{AB} = -1.39\text{N}\ (C)}$$

$$0 = 0 + F_{AF} - 1.39\sin 45° \Rightarrow \boxed{F_{AF} = 0.98\ (T)}$$

Joint E



Joint E — Calculations

Equilibrium:

$$\Sigma F_x = 0 = F_{EH} + F_{ED}\sin 45°$$
$$\Sigma F_y = 0 = E_y + F_{ED}\sin 45°$$

Solve (use $E_y = 0.98$N):

$$0 = 0.98\text{N} + F_{ED}\sin 45° \Rightarrow \boxed{F_{ED} = -1.39\text{N}\ (C)}$$

$$0 = 0 + F_{EH} - 1.39\sin 45° \Rightarrow \boxed{F_{EH} = 0.98\ (T)}$$

Zero-force members

At joint F and joint H there are two collinear members and no external forces acting on the joint, which causes a zero-force member at both BF and DH.

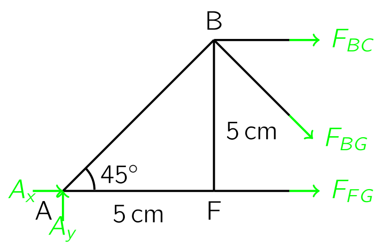
$$BG = 0\text{ N}, \quad DG = 0\text{ N}, \quad BF = 0\text{ N}, \quad DH = 0\text{ N}, \quad CG = 0\text{ N}.$$

Summary of non-zero member forces

$$AB = 1.39\text{ N }(C), \quad AF = 0.98\text{ N }(T), \quad BC = 0.98\text{ N }(C),$$
$$GF = 0.98\text{ N }(T), \quad CD = 0.98\text{ N }(C) \quad GH = 0.98\text{ N }(T),$$
$$DE = 1.39\text{ N }(C), \quad HE = 0.98\text{ N }(T).$$

Loading Condition 2

Section ABF



Section ABF — Calculations

Equilibrium:

$$\Sigma F_x = 0 = A_x + F_{FG} + F_{BC} + F_{BG} \sin 45°$$
$$\Sigma F_y = 0 = -F_{BG} \sin 45° + A_y$$
$$\Sigma M_B = 0 = A_x(0.05\text{m}) + F_{FG}(0.05\text{m}) - A_y(0.05\text{m})$$

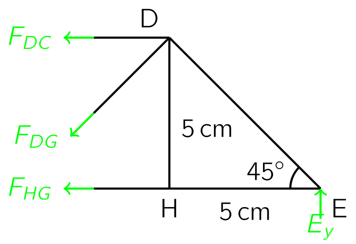
Solve (use $A_y = 0.98$ N and $A_x = 0$):

$$0 = 0(0.05\text{m}) + F_{FG}(0.05\text{m}) - 0.98\text{N}(0.05\text{m}) \Rightarrow \boxed{F_{FG} = 0.98N\ (T)}$$

$$0 = -F_{BG} \sin 45° + 0.98\text{N} \Rightarrow \boxed{F_{BG} = 1.39\text{N }(T)}$$

$$0 = 0 + 0.98\text{N} + F_{BC} + 0.98\text{N} \Rightarrow \boxed{F_{BC} = -1.96\text{N }(C)}$$

Section DHE



Section DHE — Calculations

Equilibrium:

$$\Sigma F_x = 0 = -F_{DC} - F_{HG} - F_{DG} \sin 45°$$
$$\Sigma F_y = 0 = -F_{DG} \sin 45° + E_y$$
$$\Sigma M_D = 0 = E_y(0.05\text{m}) - F_{HG}(0.05\text{m})$$

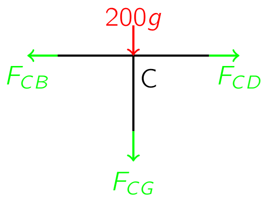
Solve (use $E_y = 0.98$ N):

$$0 = 0.98\text{N}(0.05\text{m}) - F_{HG}(0.05\text{m}) \Rightarrow \boxed{F_{HG} = 0.98N\ (T)}$$

$$0 = -F_{DG} \sin 45° + 0.98\text{N} \Rightarrow \boxed{F_{DG} = 1.39\text{N }(T)}$$

$$0 = -F_{DC} - 0.98\text{N} - 0.98 \Rightarrow \boxed{F_{DC} = -1.96\text{N }(C)}$$

Joint C



Joint C — Calculations

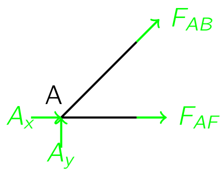
Equilibrium:

$$\Sigma F_x = 0 = F_{CD} - F_{BC}$$
$$\Sigma F_y = 0 = -1.96 - F_{CG}$$

Solve (use $F_{CD} = -1.96$N and $F_{BC} = 1.96$N):

$$\boxed{F_{CG} = -1.96\text{N } (C)}$$

Joint A



Joint A — Calculations

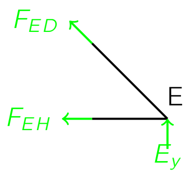
Equilibrium:

$$\Sigma F_x = 0 = A_x + F_{AF} + F_{AB} \sin 45°$$
$$\Sigma F_y = 0 = A_y + F_{AB} \sin 45°$$

Solve (use $A_y = 0.98$N and $A_x = 0$N):

$$0 = 0.98\text{N} + F_{AB} \sin 45° \Rightarrow \boxed{F_{AB} = -1.39\text{N } (C)}$$
$$0 = 0 + F_{AF} - 1.39 \sin 45° \Rightarrow \boxed{F_{AF} = 0.98\ (T)}$$

Joint E



Joint E — Calculations

Equilibrium:

$$\Sigma F_x = 0 = F_{EH} + F_{ED} \sin 45°$$
$$\Sigma F_y = 0 = E_y + F_{ED} \sin 45°$$

Solve (use $E_y = 0.98$N):

$$0 = 0.98\text{N} + F_{ED} \sin 45° \Rightarrow \boxed{F_{ED} = -1.39\text{N } (C)}$$
$$0 = 0 + F_{EH} - 1.39 \sin 45° \Rightarrow \boxed{F_{EH} = 0.98\ (T)}$$

Zero-force members

At joint F and joint H there are two collinear members and no external forces acting on the joint, which causes a zero-force member at both BF and DH.

$$BF = 0 \text{ N}, \qquad DH = 0 \text{ N}$$

Summary of non-zero force members

$$\begin{aligned} &AB = 1.39 \text{ N } (C), \quad && AF = 0.98 \text{ N } (T), \quad && BC = 0.98 \text{ N } (C) \\ &GF = 0.98 \text{ N } (T), && CD = 1.96 \text{ N } (C), && GH = 0.98 \text{ N } (T) \\ &DE = 1.39 \text{ N } (C), && HE = 0.98 \text{ N } (T). && BG = 1.39 \text{ N } (T) \\ &CG = 1.96 \text{ N } (C), && DG = 1.39 \text{ N } (T) && \end{aligned}$$

Part 4: Check your answers with online truss calculator

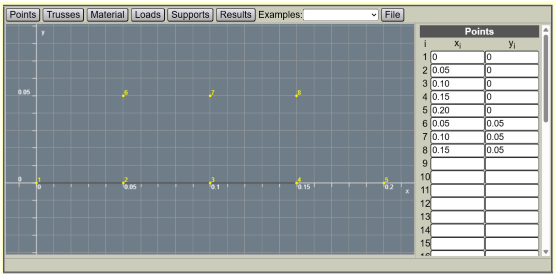


Figure 8: Defining truss nodes

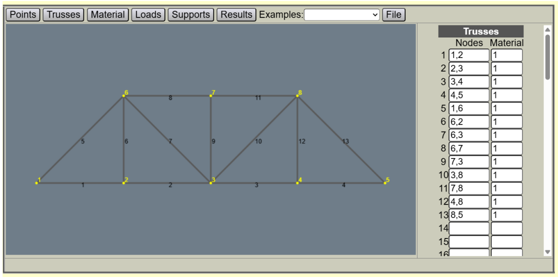


Figure 9: Defining truss beams

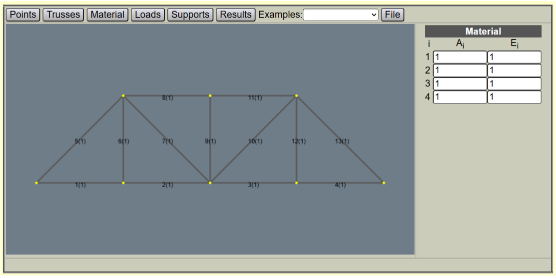


Figure 10: Material - Arbitrary

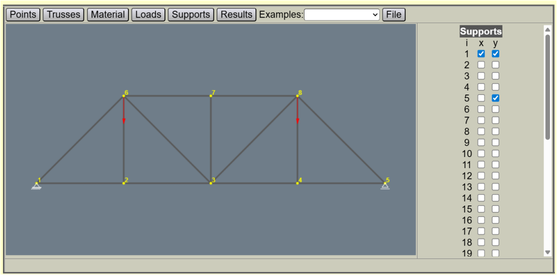


Figure 11: Defining truss beams

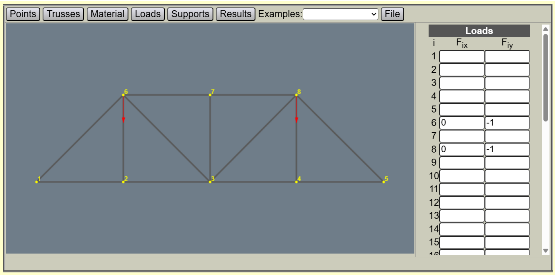


Figure 12: Loading Condition 1

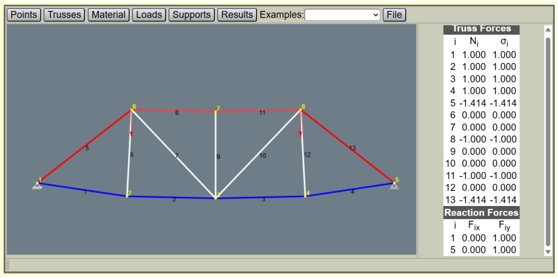


Figure 13: Member Forces and Support Reactions Condition 1

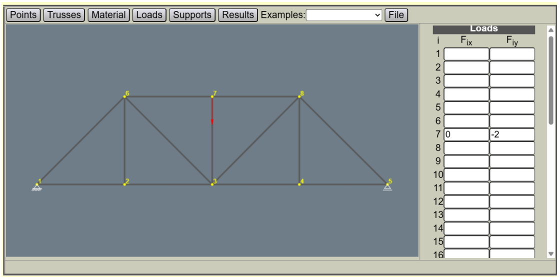


Figure 14: Loading Condition 2

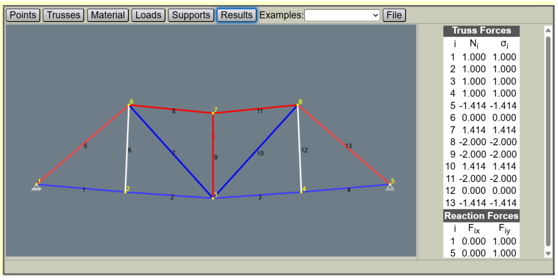


Figure 15: Member Forces and Support Reactions Condition 2

Part 5: MATLAB Truss Analysis (extra credit)

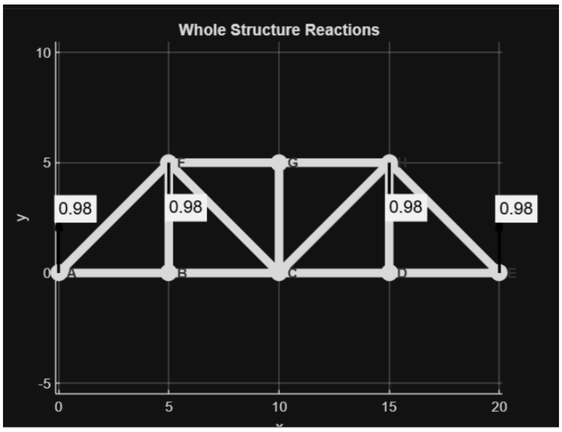


Figure 16: Loading Condition 1

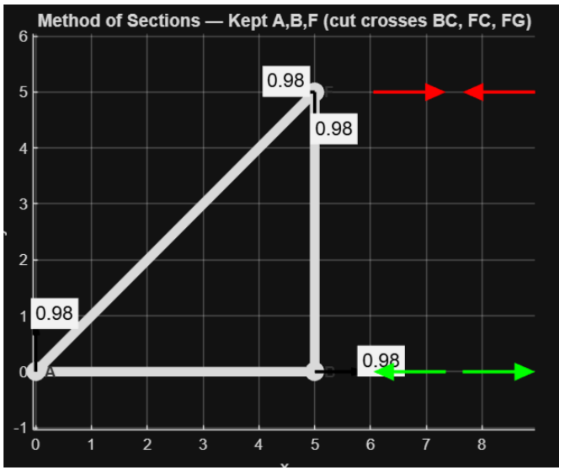


Figure 17: Member Forces in Section ABF

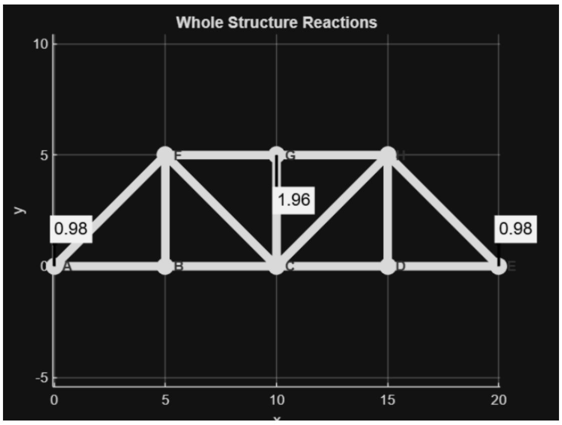


Figure 18: Loading Condition 2

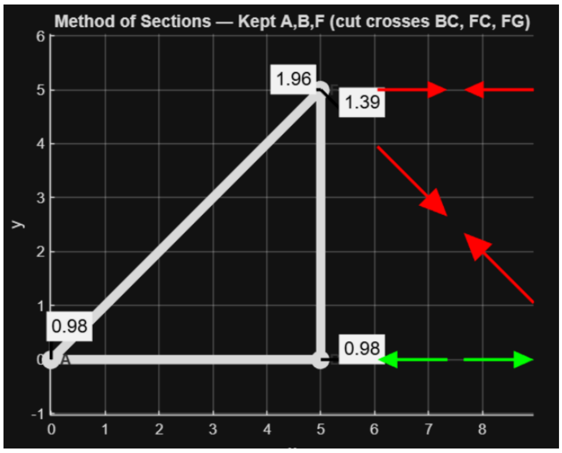


Figure 19: Member Forces in Section ABF

The results from the MATLAB code are the same as the calculations performed in part 3 and as given by the truss calculator (see the table below for all recorded MATLAB internal values).

Table 1: Comparison of Member Forces from MATLAB for Loading Conditions 1 and 2

Loading Condition 1

Member	Force (N)	Condition
AB	1.39	C
AF	0.98	T
BF	0.00	Zero
BC	0.98	C
BG	0.00	Zero
GF	0.98	T
CG	0.00	Zero
CD	0.98	C
DG	0.00	Zero
DE	1.39	C
DH	0.00	Zero
GH	0.98	T
HE	0.98	T

Loading Condition 2

Member	Force (N)	Condition
AB	1.39	C
AF	0.98	T
BF	0.00	Zero
BC	0.98	C
BG	1.39	T
GF	0.98	T
CG	1.96	C
CD	1.96	C
DG	1.39	T
DE	1.39	C
DH	0.00	Zero
GH	0.98	T
HE	0.98	T

***Note** that the MATLAB truss has its points defined differently from the points defined in all of the previous examples. As seen in the images, the nodes in the MATLAB truss are A, B, C, D, E, F, G, and H starting from the leftmost node and going right, and then starting again at the leftmost node in the top of the truss. In the table above, the labels for the beams **match the truss used throughout this document**.

***See** the attached spreadsheet for a complete summary of the internal loading forces.

Conclusion:

We found that internal member forces were symmetric for each loading condition, which confirmed what we expected. The support reactions were the same for both loading conditions due to the fact that the same load was added to the entire body (200 g) in each scenario. Our process for theoretical calculations was to work from the full body forces (loading and support reactions) to the method of sections, and finally calculating the remaining forces using the method of joints. In both loading conditions, the vertical members BF and DH were zero-force members. We used the definition of zero-force members to confirm these findings and supplement our calculations. Our calculations matched those of the Online Truss Calculator and the MATLAB program, with the only discrepancy occurring from the fact that we identified g as $9.8\frac{m}{s}^2$ and the calculators used g $= 9.81\frac{m}{s^2}$. We also were able to correctly determine whether the members were in tension or compression. Similarly, in the MATLAB calculations, we used method of sections to determine the internal loading forces of all of the beams with the exclusion of BF and DH (as per the MATLAB joint labeling). The forces of these members was calculated using the method of sections.

In completing this project we learned about the ways different parts of a truss react when experiencing loads at unique nodes. The project emphasizes that members of a truss are in pairs of members in tension and members in compression which together create a stable structure. We were able to practice using all the methods we learned to determine the forces acting on every member and support and apply these concepts to a more complex system.