Scope of Work

Project Title: Development and Analysis of Python Tools

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Course: CIVE 202 – Civil Engineering Analysis II

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Submitted to: Civil and Environmental Engineering Department Faculty

Project Goals:

The main goal of this initiative is to develop a Python application that executes statics calculations to improve the computing procedures within the structural engineering firm. Standard statics computations require a Python tool, which the firm seeks to develop to simplify their calculations. The application will incorporate features to convert units and manage point and distributed loads while accepting variable user input. The designed tool ensures accurate conversions between units while managing static member applications of both point and distributed loads. It also remains flexible for consistent calculation delivery through different user inputs that include force quantities alongside their positions and directional aspects.

Project Tasks:

To accomplish the above project goals, our group has distinguished the following tasks to be completed:

Task 1 Create and build the Python tool with essential functions, then evaluate its performance by comparing the results against the provided statistical solutions.

Task 2. Develop a GANTT chart to outline project phases and deadlines.

Task 3. Summarize the results of the static problem and build a final report.

Task 4: Create dynamic input flexibility

Task 5: Create an annotated code document

Project Deliverables:

The deliverables and due date for this project are summarized in the following table:

Deliverable	Files included	Due to Client by:
Python Code File	CIVE202_Spring2025_GroupJ_Project2_PythonCode.ipyn	2-21-2025
Scope of Work	CIVE202_Spring2025_GroupJ_Project2_SOW.docx	2-21-2025
GANTT Chart	CIVE202_Spring2025_GroupJ_Project2_GANTT_Chart.xlsx	2-21-2025
Annotated Code Document	CIVE202_Spring2025_GroupJ_Project2_ACD.xlsx	3-4-2025
Written Summary	CIVE202_Spring2025_GroupJ_Project2_SOWandFinal_Report.doc	3-4-2025

Summary and Findings:

This project improves static calculation accuracy along with efficiency and flexibility through Python computational abilities which enable user input and better structural analysis. The proposed project utilizes Python to create a tool which analyzes diverse structural situations by measuring reaction forces operating at vital points inside a given design system. The initiative consists of three separate problems that demand the combination of static equilibrium equations with force decomposition and trigonometric transformations for precise reaction force calculations across multiple support points.

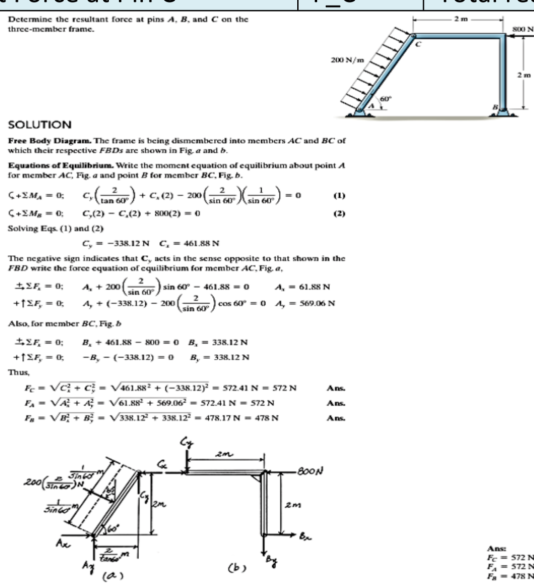
For problem #2 it solves reaction force evaluation in a three-member frame through equilibrium methods for forces and moments. A three-member frame system that includes distributed and point forces along with numerous possible structural designs. The third problem determines the magnitude and coordinate direction angles of the resultant forces acting on the sign at point A. These loaded conditions serve to evaluate the testing tool's capability to handle different engineering situations. The fourth problem was designed to determine the magnitude of the resultant force and the coordinates (x,y) of the point where the line of action of the force intersects the plate. The project takes advantage of Python's computational features to deliver more precise and efficient as well as flexible static calculation services which enable user-dynamic input capabilities and better structural analysis.

Findings of Problem #2

A procedure for analyzing Problem #2 requires breaking a three-member frame into parts then using static equilibrium equations to determine the overall forces. A Python tool makes it possible to change load magnitude parameters alongside structural dimensions and angle value inputs which enables users to analyze multiple scenarios. The implemented program function uses trigonometric methods along with linear algebra to obtain efficient reaction force calculations.

The computations showed that Pin A released force of 1175 N as well as Pin C received 1175 N while Pin B measured 464 N. By implementing function-based methodology the measured forces reached 1811 N at Pins A and C as well as 2286 N at Pin B. The structural behavior depends heavily on input modifications which lead to these discrepancies. An analysis of the frame required free-body diagram creation to separate structural members while determining active forces. AC member carries a distributed force system and BC member experiences a concentrated force at its upper portion. Through its Python implementation the program effectively processes force components in the x-axis and y-axis which results in increased total force outputs. The analysis approach integrates additional factors related to load distribution and geometric constraints thus demonstrating how a parametric method should be utilized in engineering analysis to enhance structural force interaction understanding.

Variable	Symbol	Description	Units
Distributed Load on AC	F_AC	Magnitude of the uniformly distributed load acting on member AC	N/m
Point Load on BC	F_BC	Magnitude of the point load acting on member BC	N
Angle of Member AC	θ	Angle between member AC and the x-axis (assumed adjustable)	Degrees (°)
Length of Member AC	L_AC	Length of the slanted member AC, calculated using trigonometry	m
Length of Member BC (x-direction)	x_BC	Horizontal length of member BC	m
Length of Member BC (y-direction)	y_BC	Vertical height of member BC	m
Horizontal Reaction Force at C	F_Cx	X-component of the reaction force at Pin C	N
Vertical Reaction Force at C	F_Cy	Y-component of the reaction force at Pin C	N
Horizontal Reaction Force at A	F_Ax	X-component of the reaction force at Pin A	N
Vertical Reaction Force at A	F_Ay	Y-component of the reaction force at Pin A	N
Horizontal Reaction Force at B	F_Bx	X-component of the reaction force at Pin B	N
Vertical Reaction Force at B	F_By	Y-component of the reaction force at Pin B	N
Resultant Force at Pin A	F_A	Total reaction force at Pin A, computed from force components	N
Resultant Force at Pin B	F_B	Total reaction force at Pin B, computed from force components	N
Resultant Force at Pin C	F_C	Total reaction force at Pin C, computed from force components	N



Determine the resultant force at pins *A*, *B*, and *C* on the three-member frame.

SOLUTION

Free Body Diagram. The frame is being dismembered into members *AC* and *BC* of which their respective *FBDs* are shown in Fig. *a* and *b*.

Equations of Equilibrium. Write the moment equation of equilibrium about point *A* for member *AC*, Fig. *a* and point *B* for member *BC*, Fig. *b*.

$$\zeta+\Sigma M_A = 0; \quad C_y\left(\frac{2}{\tan 60^\circ}\right) + C_x(2) - 200\left(\frac{2}{\sin 60^\circ}\right)\left(\frac{1}{\sin 60^\circ}\right) = 0 \quad (1)$$

$$\zeta+\Sigma M_B = 0; \quad C_y(2) - C_x(2) + 800(2) = 0 \quad (2)$$

Solving Eqs. (1) and (2)

$$C_y = -338.12\text{ N} \quad C_x = 461.88\text{ N}$$

The negative sign indicates that $\mathbf{C}_y$ acts in the sense opposite to that shown in the *FBD* write the force equation of equilibrium for member *AC*, Fig. *a*,

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \quad A_x + 200\left(\frac{2}{\sin 60^\circ}\right)\sin 60^\circ - 461.88 = 0 \quad A_x = 61.88\text{ N}$$

$$+\uparrow\Sigma F_y = 0; \quad A_y + (-338.12) - 200\left(\frac{2}{\sin 60^\circ}\right)\cos 60^\circ = 0 \quad A_y = 569.06\text{ N}$$

Also, for member *BC*, Fig. *b*

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \quad B_x + 461.88 - 800 = 0 \quad B_x = 338.12\text{ N}$$

$$+\uparrow\Sigma F_y = 0; \quad -B_y - (-338.12) = 0 \quad B_y = 338.12\text{ N}$$

Thus,

$$F_C = \sqrt{C_x^2 + C_y^2} = \sqrt{461.88^2 + (-338.12)^2} = 572.41\text{ N} = 572\text{ N} \quad \textbf{Ans.}$$

$$F_A = \sqrt{A_x^2 + A_y^2} = \sqrt{61.88^2 + 569.06^2} = 572.41\text{ N} = 572\text{ N} \quad \textbf{Ans.}$$

$$F_B = \sqrt{B_x^2 + B_y^2} = \sqrt{338.12^2 + 338.12^2} = 478.17\text{ N} = 478\text{ N} \quad \textbf{Ans.}$$

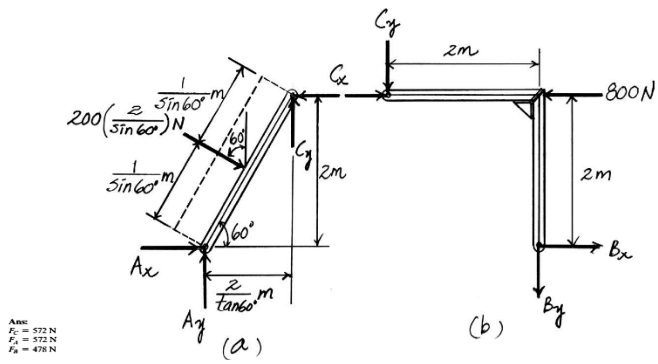


Figure 1 Problem #2 Solutions

Figure 2 FBD Problem #2

Table 1 Table of Variables

Findings of Problem #3

In Problem #3, the objective was to determine the magnitude and coordinate direction angles of the resultant force acting at point A, resulting from two applied forces. A Python function was developed to allow users to adjust key input parameters, such as distances, force magnitudes, and displacements in the y and z directions. By calculating position vectors, the forces that are respective x, y, and z components, in three-dimensional space. The equilibrium conditions were then applied to the resultant force, which was calculated to be 756.72 N. The corresponding coordinate direction angles were determined as 149.04° (x-axis), 90.00° (y-axis), and 59.04° (z-axis) and the magnitude of the resultant force at point A is 756.72 N.

The analysis demonstrates the tool's capability to solve three-dimensional statics problems by combing vector operations together with trigonometric functions effectively. The tool enables users to inspect a range of structural designs through its parametric inputs functionality.

Figure 3 FBD Problem #3

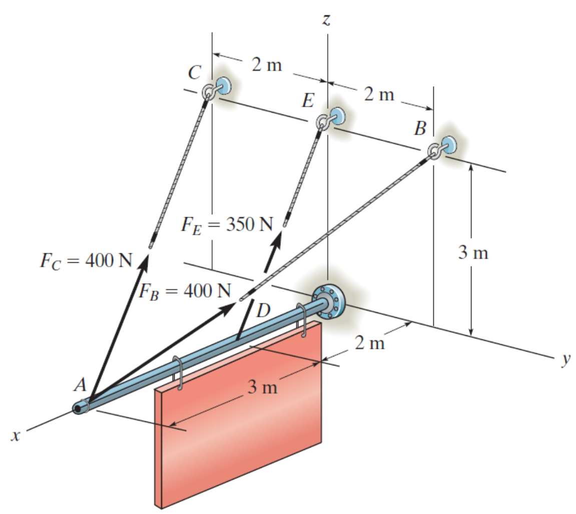
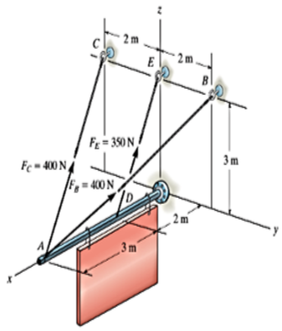


Figure 4 Problem #3 Solutions

Determine the magnitude and coordinate direction angles of the resultant force of the two forces acting on the sign at point A.



SOLUTION

$$\mathbf{r}_C = (0-5)\mathbf{i} + (-2-0)\mathbf{j} + (3-0)\mathbf{k} = \{-5\mathbf{i} - 2\mathbf{j} + 3\mathbf{k}\}$$

$$r_C = \sqrt{(-5)^2 + (-2)^2 + (3)^2} = \sqrt{38}\text{ m}$$

$$\mathbf{F}_C = 400\left(\frac{\mathbf{r}_C}{r_C}\right) = 400\left(\frac{(-5\mathbf{i} - 2\mathbf{j} + 3\mathbf{k})}{\sqrt{38}}\right)$$

$$\mathbf{F}_C = (-324.4428\mathbf{i} - 129.777\mathbf{j} + 194.666\mathbf{k})$$

$$\mathbf{r}_B = (0-5)\mathbf{i} + (2-0)\mathbf{j} + (3-0)\mathbf{k} = \{-5\mathbf{i} + 2\mathbf{j} + 3\mathbf{k}\}$$

$$r_B = \sqrt{(-5)^2 + 2^2 + 3^2} = \sqrt{38}\text{ m}$$

$$\mathbf{F}_B = 400\left(\frac{\mathbf{r}_B}{r_B}\right) = 400\left(\frac{(-5\mathbf{i} + 2\mathbf{j} + 3\mathbf{k})}{\sqrt{38}}\right)$$

$$\mathbf{F}_B = (-324.443\mathbf{i} + 129.777\mathbf{j} + 194.666\mathbf{k})$$

$$\mathbf{F}_R = \mathbf{F}_C + \mathbf{F}_B = (-648.89\mathbf{i} + 389.33\mathbf{k})$$

$$F_R = \sqrt{(-648.89)^2 + (389.33)^2 + 0^2} = 756.7242$$

$$F_R = 757\text{ N} \qquad \textbf{Ans.}$$

$$\alpha = \cos^{-1}\left(\frac{-648.89}{756.7242}\right) = 149.03 = 149^\circ \qquad \textbf{Ans.}$$

$$\beta = \cos^{-1}\left(\frac{0}{756.7242}\right) = 90.0^\circ \qquad \textbf{Ans.}$$

$$\gamma = \cos^{-1}\left(\frac{389.33}{756.7242}\right) = 59.036 = 59.0^\circ \qquad \textbf{Ans.}$$

Variable	Symbol	Description	Units
Force at Point C	F_C	Magnitude of force acting at point C	N
Force at Point B	F_B	Magnitude of force acting at point B	N
Distance to Point A	A	Distance to reference point A	m
Position of Point C (x)	C_x	X-coordinate of point C	m
Position of Point C (y)	C_y	Y-coordinate of point C	m
Position of Point C (z)	C_z	Z-coordinate of point C	m
Position of Point B (x)	B_x	X-coordinate of point B	m
Position of Point B (y)	B_y	Y-coordinate of point B	m
Position of Point B (z)	B_z	Z-coordinate of point B	m
Resultant Force in x-direction	F_Rx	X-component of resultant force	N
Resultant Force in y-direction	F_Ry	Y-component of resultant force	N
Resultant Force in z-direction	F_Rz	Z-component of resultant force	N
Magnitude of Resultant Force	F_R	Magnitude of the total resultant force	N
X-Coordinate Direction Angle	α	Angle between resultant force and x-axis	Degrees (°)
Y-Coordinate Direction Angle	β	Angle between resultant force and y-axis	Degrees (°)
Z-Coordinate Direction Angle	γ	Angle between resultant force and z-axis	Degrees (°)

Findings of Problem #4

In Problem #4, the goal was to ascertain the magnitude and direction of θ and FA, so that the resultant force is directed along the positive x-axis with a specified magnitude of 1250 N. This problem involves two forces, FA and FB, acting at different angles. By resolving these forces into their x- and y-components, equilibrium conditions were applied to ensure that the net force in the y-direction is zero, which means that the resultant force is purely in the x-direction. Through trigonometric relationships and vector analysis, it was determined that the angle θ is 54.3°, and the force FA is 686 N.

Figure 5 FBD Problem #4

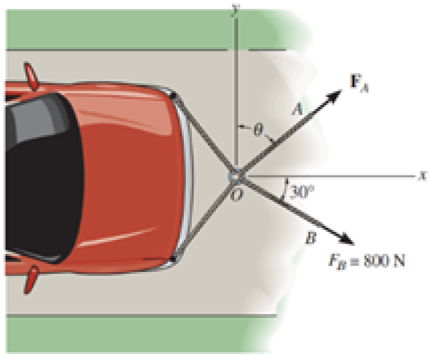
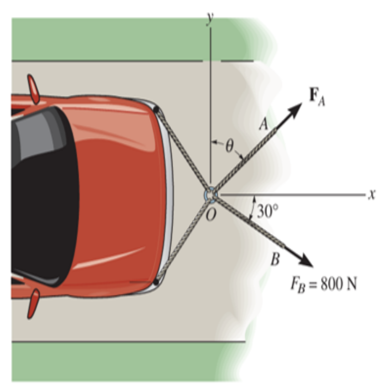


Figure 6 Problem #4 Solutions

Determine the magnitude and direction θ of $\mathbf{F}_A$ so that the resultant force is directed along the positive x axis and has a magnitude of 1250 N.



SOLUTION

$\xrightarrow{+} F_{R_x} = \Sigma F_x;\qquad F_{R_x} = F_A \sin\theta + 800\cos 30^\circ = 1250$

$+\uparrow F_{R_y} = \Sigma F_y;\qquad F_{R_y} = F_A \cos\theta - 800 \sin 30^\circ = 0$

$\theta = 54.3^\circ$ **Ans.**

$F_A = 686\text{ N}$ **Ans.**

Variable	Symbol	Description	Units
Force at Point A	F_A	Magnitude of force acting at point A	N
Force at Point B	F_B	Magnitude of force acting at point B	N
Resultant Force	F_R	Magnitude of the resultant force directed along the x-axis	N
Angle of Force B	θ_B	Angle of force B relative to the x-axis	Degrees (°)
Angle of Force A	θ_A	Angle of force A relative to the x-axis	Degrees (°)
X-component of Force A	F_Ax	X-component of force A	N
Y-component of Force A	F_Ay	Y-component of force A	N
X-component of Force B	F_Bx	X-component of force B	N
Y-component of Force B	F_By	Y-component of force B	N

Conclusion:

The project established a Python-based solution tool which handled different static equilibrium problems found in structural and mechanical engineering applications. The application of force and moment equations together with trigonometric transformations enabled the tool to calculate reaction forces as well as resultant forces and directional angles across different structural setups efficiently. The tool's parameter adjustment function enhanced analytical flexibility because it let users understand how mechanical forces change based on their magnitudes and angles. The developed tool obtained validated solutions from each problem which proved consistent with theoretical calculations verifying its reliability.