

# Arch314

# **STRUCTURES I**

Fall 2025  
Recitation

FACULTY: Prof. Peter von Bülow  
Mohsen Vatandoost

# Arch314: STRUCTURES I

Welcome to the Recitation session 10/10

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Office hours:

Room 3228

Wed: 11:30 – 12:00

Mon, Fri: 11:30 - 12:00

By appointment

Please feel free to ask questions.

# Arch314: STRUCTURES I

## Welcome to the Recitation session 10/10

### Outline:

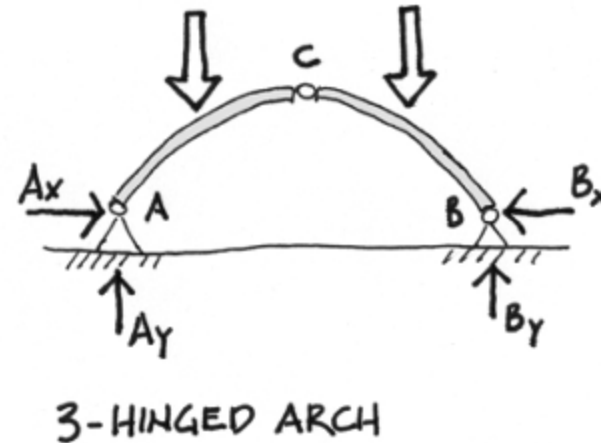
- Quick **Recap** of the week
- Provide the solution for the assignment (**Homework 8**)
- Answering students' questions
- Lab: **3-Hinged Arches**
- **Bridge\_1** project (Due date: this weekend)

Please feel free to ask questions.

# Recap of the week

## 3-Hinged Arch

The 3-Hinged Arch has a “hinge” at each pinned support **plus one more internally**. The internal hinge provides one additional statics equation to be written since the moment at C is known ( $M_C = 0$ ). This makes the system **statically determinate**.



## Characteristics of a 3-Hinged Arch

- Statically determinate – can be calculated with statics
- Movement or settling of foundations will not alter member stresses
- Small fabrication errors in length do not affect internal stresses
- Hinge placement can reduce internal stresses

# Provide the solution for the assignment – HW8

## 9. Three Hinged Arches

For the three-hinged arch shown, determine horizontal and vertical components of each reaction, and the moments at the knees.

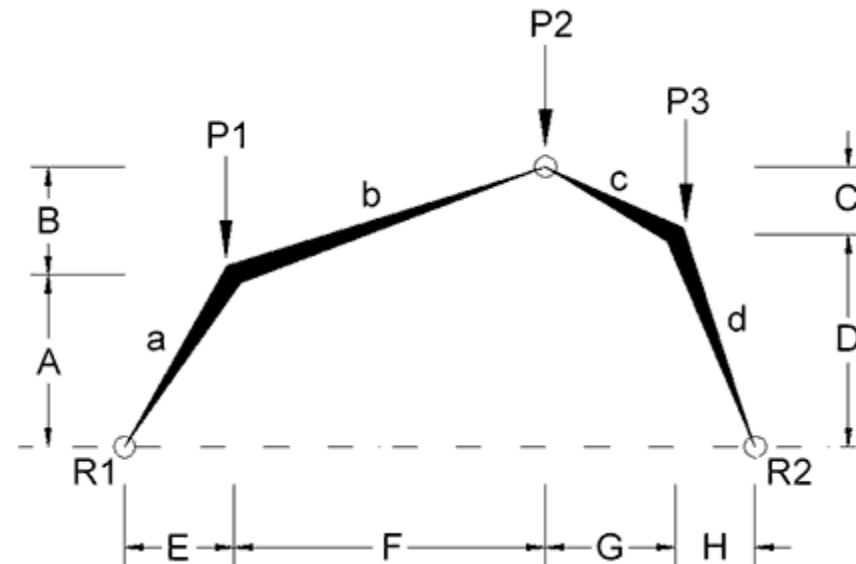
DATASET: 1

-2-

-3-

Height A	13 FT
Height B	8 FT
Height C	11 FT
Height D	10 FT
Length E	4 FT
Length F	17 FT
Length G	17 FT
Length H	4 FT
Force P1	6 KIPS
Force P2	20 KIPS
Force P3	20 KIPS

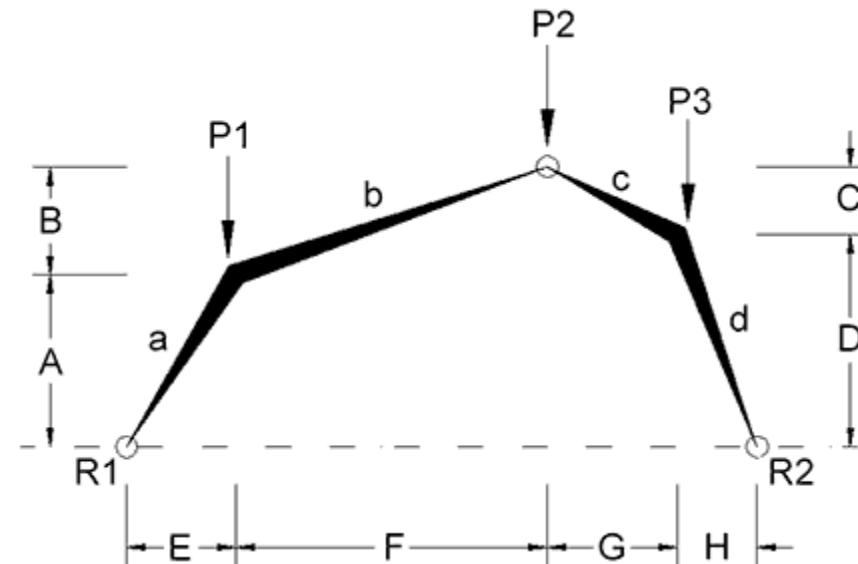
- Problem:



# Provide the solution for the assignment – HW8

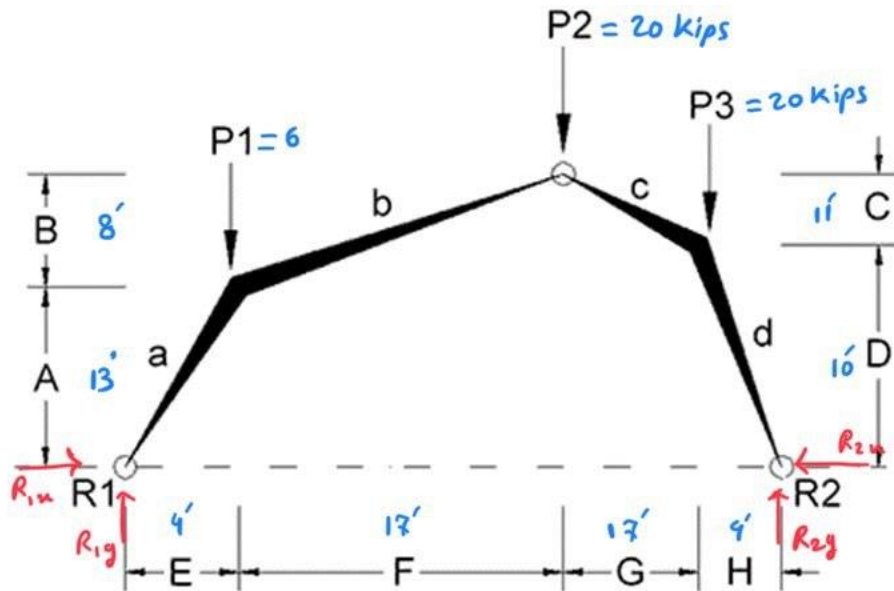
- Problem:

#	Question	Your Response
1	HORIZONTAL component of R1 (+ = to the right)	<input type="text"/> KIPS
2	VERTICAL component of R1 (+ = upward)	<input type="text"/> KIPS
3	HORIZONTAL component of R2 (+ = to the right)	<input type="text"/> KIPS
4	VERTICAL component of R2 (+ = upward)	<input type="text"/> KIPS
5	Moment at M1 (+ = tension inside)	<input type="text"/> KIP-FT
6	Moment at M2 (+ = tension inside)	<input type="text"/> KIP-FT
7	Axial force in member "a" (+ is compression)	<input type="text"/> KIPS
8	Axial force in member "b" (+ is compression)	<input type="text"/> KIPS
9	Axial force in member "c" (+ is compression)	<input type="text"/> KIPS
10	Axial force in member "d" (+ is compression)	<input type="text"/> KIPS



# Provide the solution for the assignment – HW8

- Solution:



FBD of whole structure:

$$\sum M_{@a} = 0$$

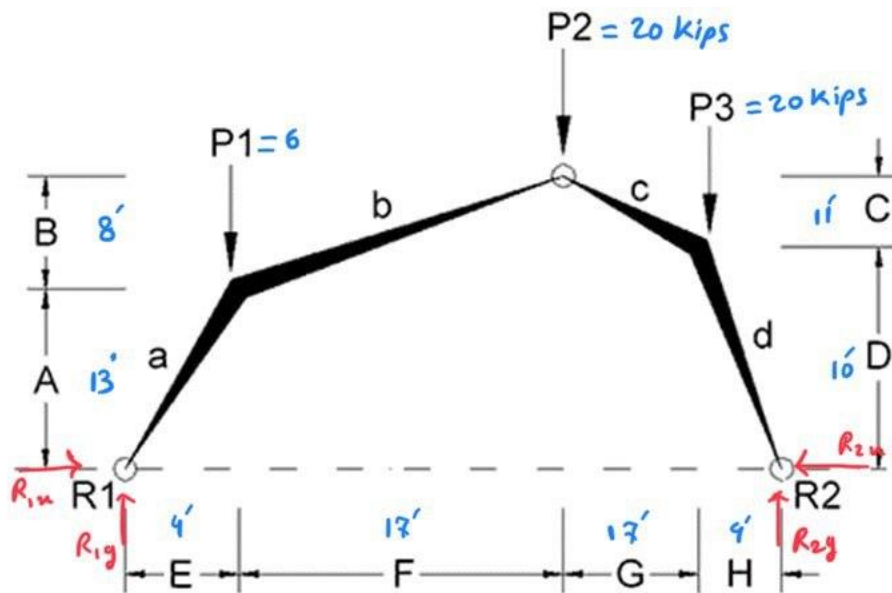
$$P_1 \times E + P_2 \times (E+F) + P_3 \times (E+F+G) - R_{2y} \times (E+F+G+H) = 0$$

$$6 \times 4 + 20 \times (4+18) + 20 \times (4+18+17) - R_{2y} \times (4+18+17+4) = 0$$

$$\rightarrow R_{2y} = 28.667 \text{ kips}$$

# Provide the solution for the assignment – HW8

- Solution:



$$\sum M_{@2} = .$$

$$-P_3 \times H - P_2 \times (G+H) - P_1 \times (E+F+G+H) + R_{1y} \times (E+F+G+H) = .$$

$$-20 \times 4 - 20 \times (17+4) - 6 \times (4+17+17) + R_{1y} \times (4+17+17+4) = .$$

$$\rightarrow R_{1y} = 17.334 \text{ kips}$$

check :

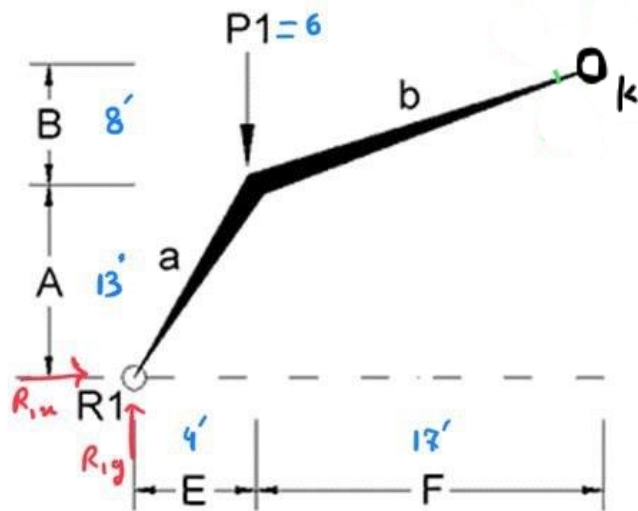
$$\sum F_y = .$$

$$R_{1y} - P_1 - P_2 - P_3 + R_{2y} = ?$$

$$17.334 - 6 - 20 - 20 + 28.667 = ? \rightarrow \text{OK} \checkmark$$

# Provide the solution for the assignment – HW8

- Solution:



FBD Left part:

$$\sum M_{@k} = 0$$

$$-P_1 \times F + R_{1y} \times (E+F) - R_{1x} \times (A+B) = 0$$

$$-6 \times 17 + 17.334 \times (4+13) - R_{1x} \times (13+8) = 0$$

$$\rightarrow R_{1x} = 12.476 \text{ kips}$$

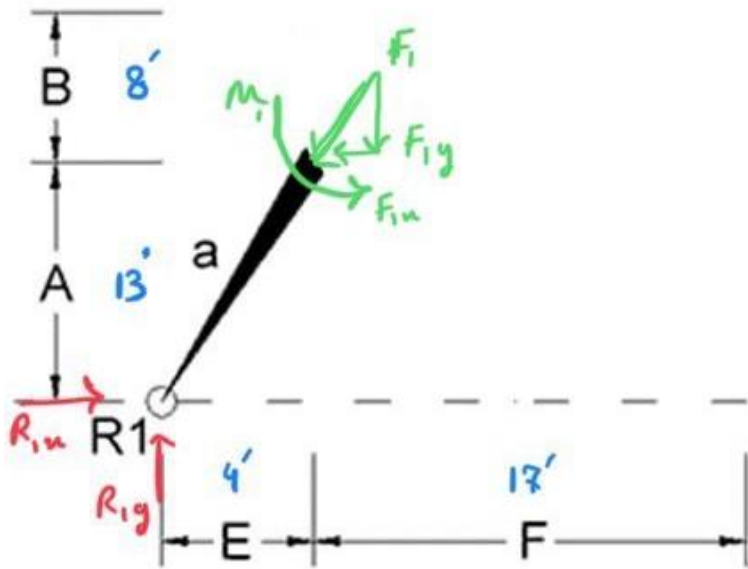
FBD of whole structure:

$$\sum F_x = 0 \rightarrow R_{1x} - R_{2x} = 0$$

$$\rightarrow R_{1x} = R_{2x} = 12.476$$

# Provide the solution for the assignment – HW8

- Solution:



FBD:

$$\sum F_x = 0 \rightarrow R_{1x} - F_{ix} = 0 \rightarrow F_{ix} = R_{1x} = \underline{12.476} \text{ kips}$$

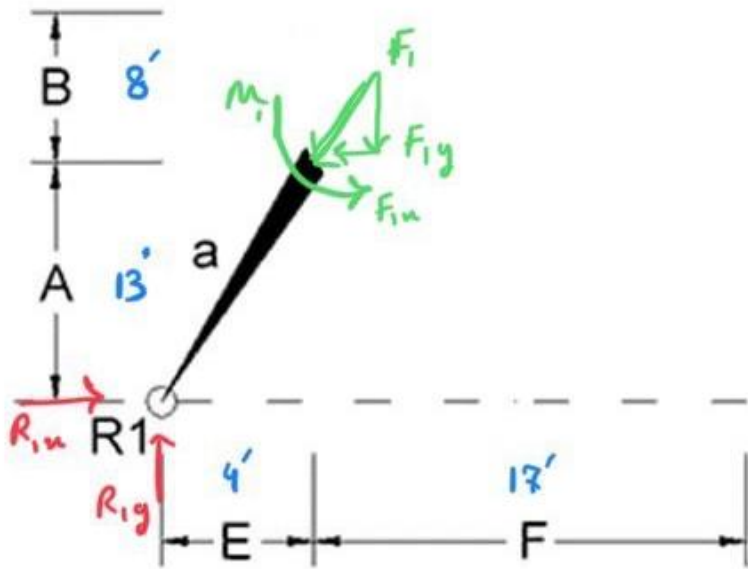
$$\sum F_y = 0 \rightarrow R_{1y} - F_{iy} = 0 \rightarrow F_{iy} = R_{1y} = \underline{17.334} \text{ kips}$$

$$F_i = \sqrt{F_{ix}^2 + F_{iy}^2} = \sqrt{12.476^2 + 17.334^2} = \underline{21.35} \text{ kips}$$

Axial Force in member: Compression

# Provide the solution for the assignment – HW8

- Solution:



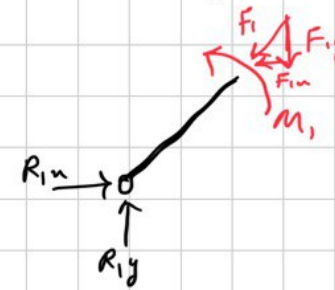
$$\sum M_{@A} = 0$$

$$\rightarrow F_{iy} \times E - F_{ix} \times A - M_i = 0$$

$$17.334 \times 4 - 12.476 \times 13 - M_i = 0$$

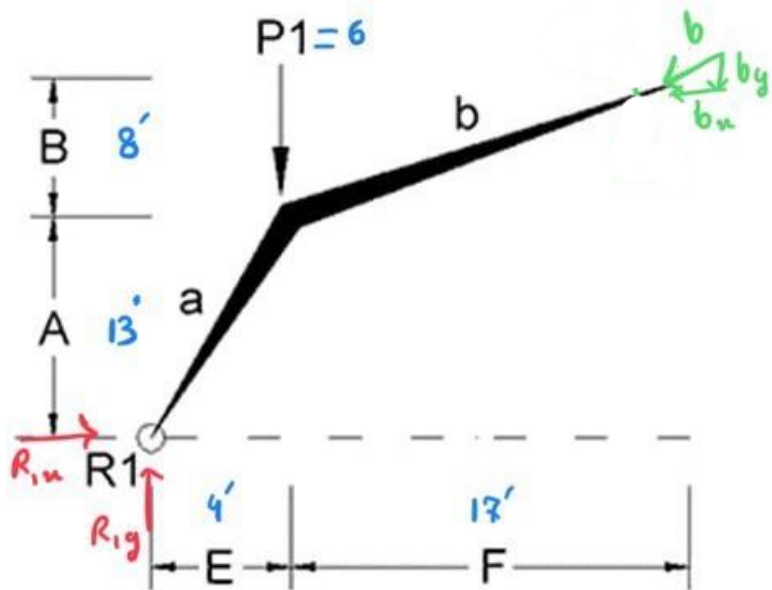
$$\rightarrow M_i = -92.852 \text{ kips}\cdot\text{ft}$$

The negative value indicates our initial assumption was not right, so we should flip the direction



# Provide the solution for the assignment – HW8

- Solution:



FBD:

$$\sum F_x = 0 \rightarrow R_{1x} - b_n = 0 \rightarrow b_n = R_{1x} = 12.476 \text{ kips}$$

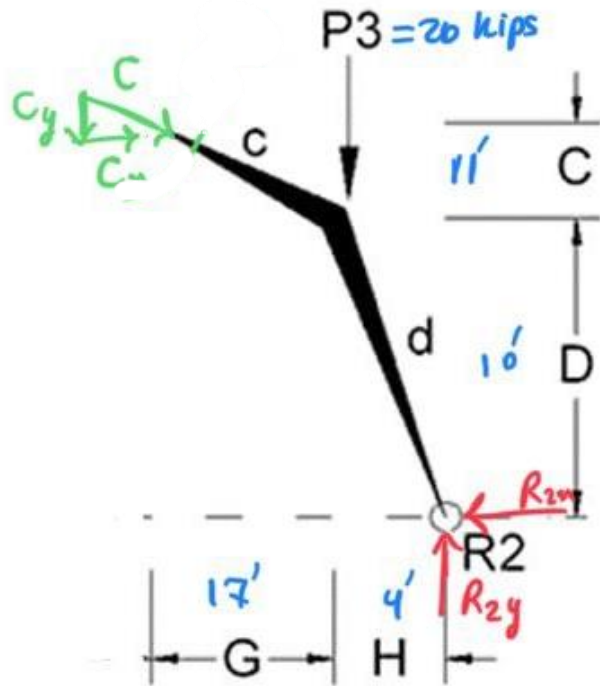
$$\sum F_y = 0 \rightarrow R_{1y} - P_1 - b_y = 0 \rightarrow 17.334 - 6 - b_y = 0$$

$$\rightarrow b_y = 11.334 \text{ kips}$$

$$b = \sqrt{b_n^2 + b_y^2} = \sqrt{12.476^2 + 11.334^2} = 16.855 \text{ kips}$$

Compression

# Provide the solution for the assignment – HW8



FBD Right part:

$$\sum F_x = 0 \rightarrow C_x - R_{2x} = 0 \rightarrow C_x = R_{2x} = \underline{12.976} \text{ kips}$$

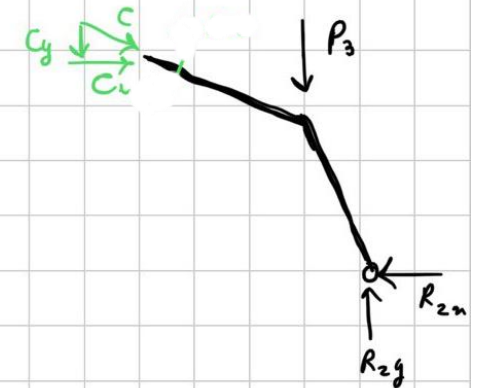
$$\sum F_y = 0 \rightarrow -C_y - P_3 + R_{2y} = 0 \rightarrow -C_y - 20 + 28.667 = 0$$

$$\rightarrow C_y = 8.667$$

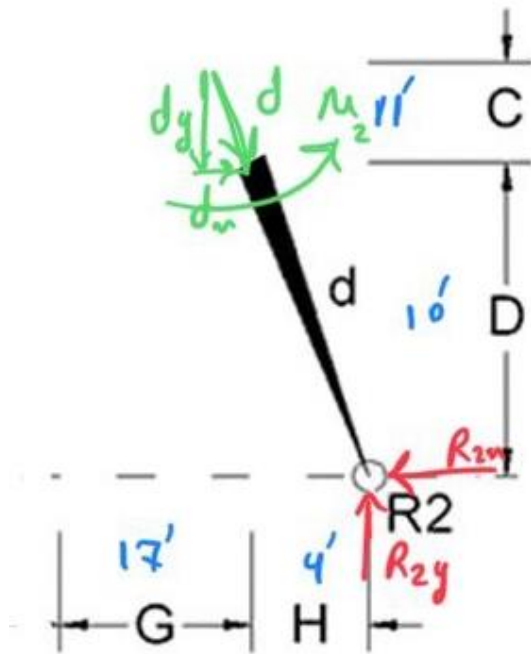
we should flip the direction

$$C = \sqrt{C_x^2 + C_y^2} = \sqrt{12.976^2 + 8.667^2}$$

$$\rightarrow C = \underline{15.19} \text{ kips}$$



# Provide the solution for the assignment – HW8



FBD:

$$\sum F_x = 0 \rightarrow d_x - R_{2x} = 0 \rightarrow d_x = R_{2x} = \underline{12.476} \text{ kips}$$

$$\sum F_y = 0 \rightarrow R_{2y} - d_y = 0 \rightarrow d_y = R_{2y} = \underline{28.667} \text{ kips}$$

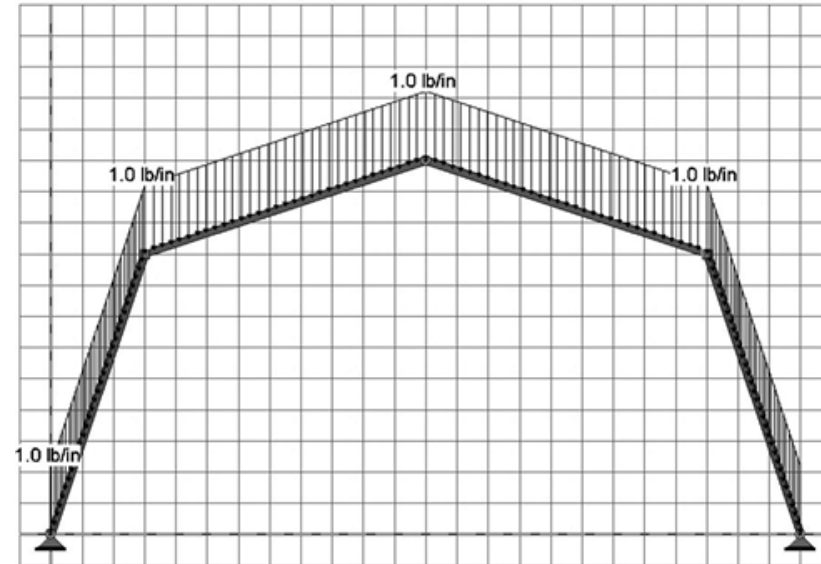
$$d = \sqrt{d_x^2 + d_y^2} = \sqrt{12.476^2 + 28.667^2} = \underline{31.26} \text{ kips}$$

$$\sum M_{@2} = 0 \rightarrow d_x \times D - d_y \times H - M_2 = 0$$

$$12.476 \times 10 - 28.667 \times 4 - M_2 = 0$$

$$\rightarrow \underline{M_2 = 10.092} \text{ kips-ft}$$

# Lab: 3-Hinged Arches



## Description

This project finds the reactions and moments of a three-hinged arches.

## Goals

- To observe the end thrust behavior of a three-hinged arch.
- To calculate the end reactions of the arch.
- To calculate the moment at the knee.
- To find the geometry of a catenary arch.

# Lab: 3-Hinged Arches

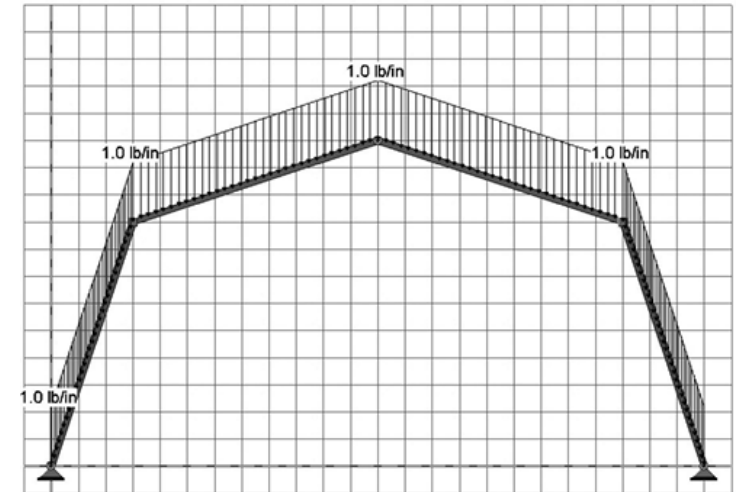
## Procedure

### Part 1

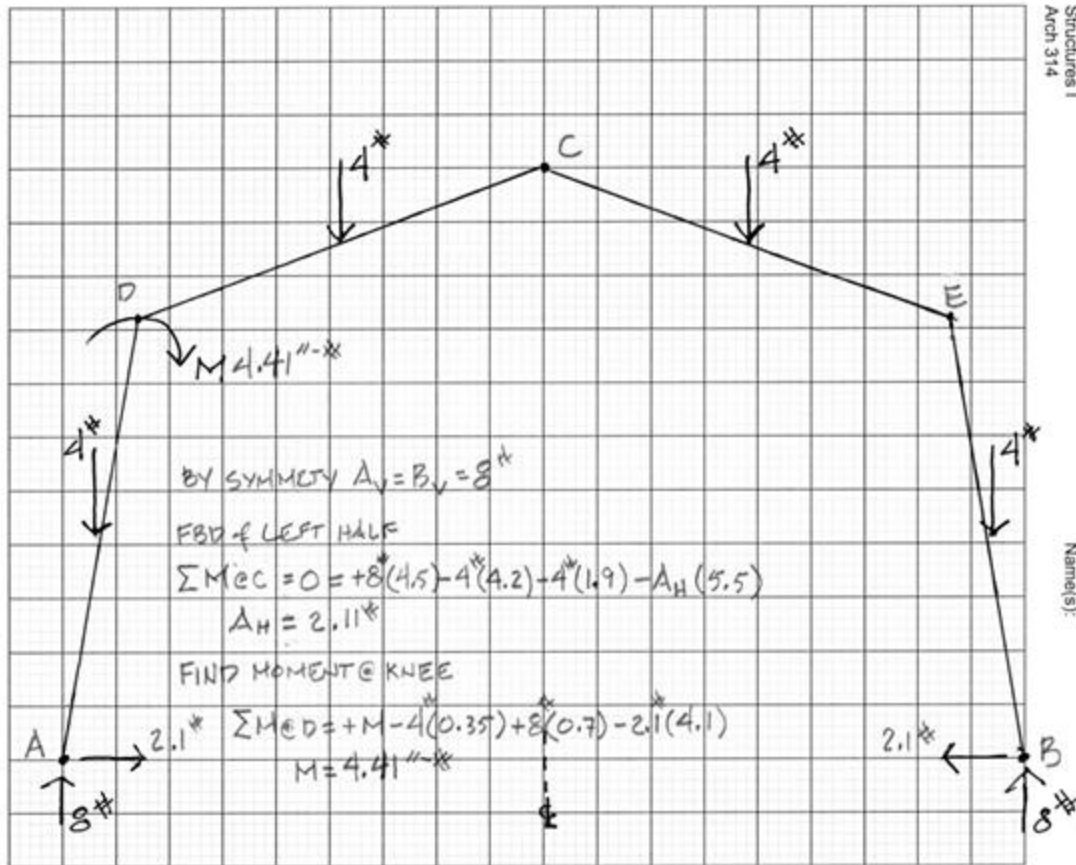
1. Adjust the 3-hinged arch model on graph paper to have a 9" span.
2. Copy the geometry onto graph paper to determine the dimensions – the member lengths should be about 4" each.
3. Assume a uniform vertical load of 1 pound / inch on the length of each member (like a selfweight). Find and locate the resultant forces on your drawing.
4. Calculate the end reactions.
5. Calculate the peak moment at the knee.

### Part 2

6. Next use the string to find a funicular shape with the same span.
7. Copy the new geometry onto the graph paper (overlaid on the original arch) to determine the dimensions.
8. Segment the arch into four symmetric sections.
9. Calculate the end reactions.
10. Calculate the peak moment at the knee.



# Lab: 3-Hinged Arches



## PART 1

VERTICAL REACTIONS - BY SYMMETRY

$$\sum F_V = 16 - R_1 - R_2 = 0$$

$$R_1 = R_2 = \boxed{8^k}$$

FBD LEFT SIDE

$$\sum M_e = 0 = 8(4.5) - H(5.5) - 4(4.2) - 4(1.9)$$

$$H = \boxed{2.1^k}$$

RIGHT SIDE BY SYMMETRY

$$M_{\text{KNEE}} = 8(0.7) - 2.1(4.1) - 4(0.35) + H = 0$$

$$M = \boxed{4.41^k}$$

## PART 2

AGAIN VERTICAL REACTIONS BY SYMMETRY

$$R_V = \boxed{8^k}$$

FBD LEFT SIDE

$$\sum M_e = 0 = 8(4.5) - 5(3.5) - 3(1.2) - H(6.3)$$

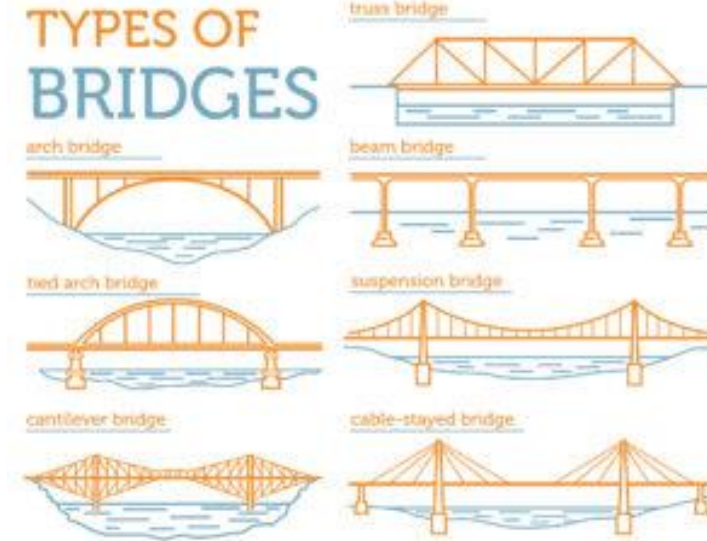
$$H = \boxed{2.3^k}$$

$$M_{\text{KNEE}} = 8(2) - 2.37(4.6) - 5(1) - M = 0$$

$$M = \boxed{0.1 \approx 0}$$

# Bridge Project

## Truss Bridge



### Description

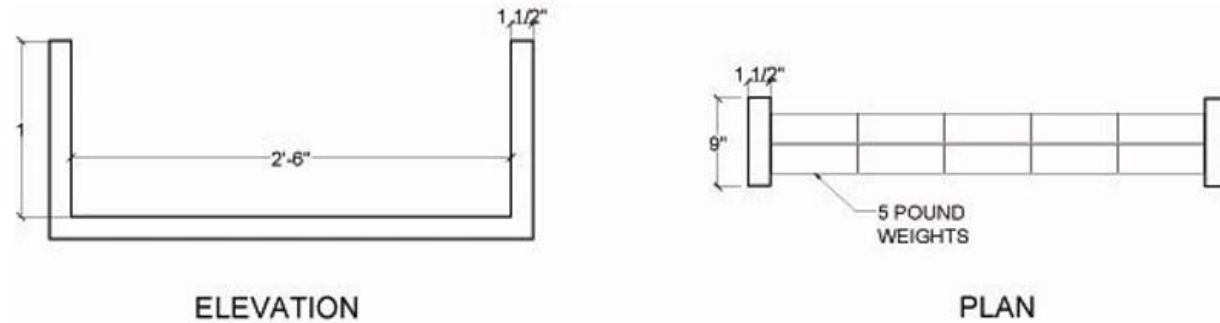
This project gives students the chance to apply concepts learned in truss analysis to the design of a small road bridge. The project also introduces techniques for design and testing of structural models. Work is to be conducted in groups of up to four people. The project is divided into three parts: 1) initial conceptual design and analysis, 2) design development and testing, 3) post analysis and documentation.

### Objectives

- to explore the geometric design parameters of a structural truss through bridge design.
- to perform quantitative analysis as a means of testing and evaluating a design.
- to test a design concept using a 1:64 ( $3/16'' = 1'$ ) scale structural model.
- to document the results in a clear, well organized report.

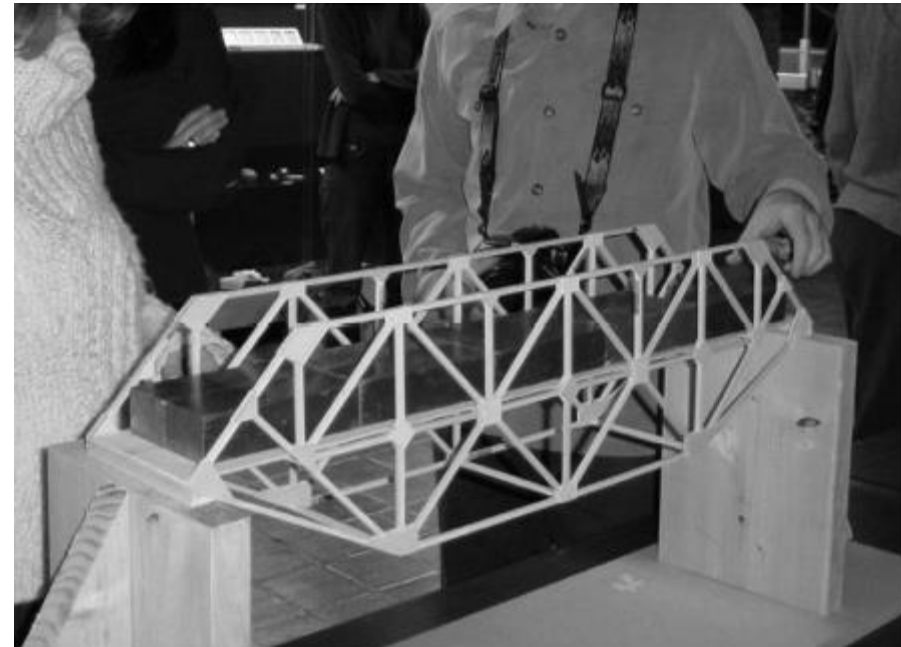
# Bridge Project

Testing Frame:



Span=160 ft (scaled = 30 in)  
Max. Depth = 53 ft (10 in)  
Max. Deck = 8 in (1/8 in thick)

Max Weight = 68k (4 oz)  
Material = wood + glue



# Bridge Project

- Have creativity!
- Refine your initial design
- Iteration to upgrade your design
- Pay attention to the Tally sheet requirements.  
(We Don't want you to lose points!)
- A long-continuous member is allowed.
- Deck required to be designed flat
- Look at the examples provided in the course website

# Bridge Project

## Documentation

see tally sheet for detail  
development of prelim  
revised analysis  
final design  
test results  
post-test analysis

## Score Tally

### Three Parts

prelim report	40
testing	60
final report	150

## Preliminary Report

### Explanation

concept  
truss type

### Analysis

member forces (Dr Frame)  
member sizing  
selfweight  
capacity

### Presentation

letter size report

### Due Date

12 October 2023

## Criteria

dimensions – 30" span  
loading – 50 lbs min.  
Materials – wood + glue

## Efficiency score

weight limit – 4 oz. (minimize)  
load capacity – 50 lb (maximize)  
 $(4/\text{weight}) \times 50 + (\text{load}/50) \times 9$

## Submission

preliminary report  
model testing  
final report

## Final Report

### Documentation

see tally sheet for detail  
development of prelim  
revised analysis  
final design  
test results  
post-test analysis

# Bridge Project

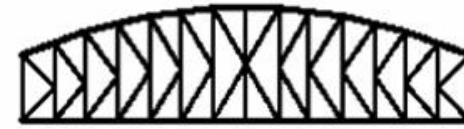
Remember!  
Triangles are Sturdy, Stable Shapes



Pratt



Parker



K-Truss



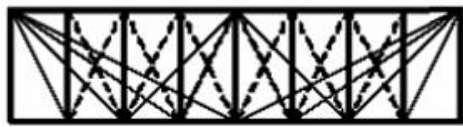
Howe



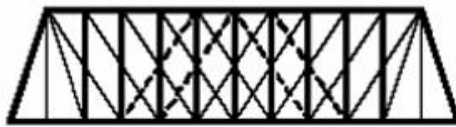
Camelback



Warren



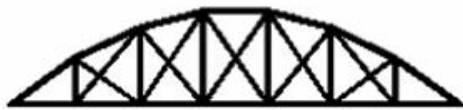
Fink



Double Intersection Pratt



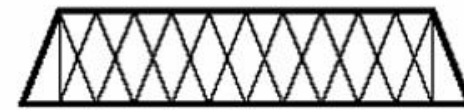
Warren (with Verticals)



Bowstring



Baltimore



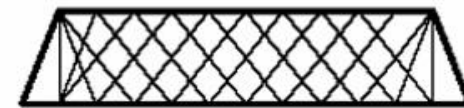
Double Intersection Warren



Waddell "A" Truss



Pennsylvania



Lattice

# Bridge Project — Some good examples



Arch314: STRUCTURES I

Thank you.

Any question?

Please feel free to ask questions.