

# Arch 314- Structures I

Recitation 006



Vishakha Bagarao

6th Sept 2024



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## Contents

- Overview
- Quick Recap
  - Vertical & Lateral loads on the structure
    - Problem Set 01
  - Static & Vector Additions
    - Problem Set 02
- Lab 1- Adding Forces

# Syllabus

Architecture 314  
3 credit hours

<http://www.structures1.tcaup.umich.edu/>  
Fall 2024

## ARCHITECTURAL STRUCTURES I Syllabus

**Dr.-Ing. Peter von Buelow**  
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Lecture MW 10:30 – 11:30  
Recitation F (five sections)  
(by appointment)

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### Catalog Description

This course covers the basic principles of architectural structures, including: the influence of geometric, sectional, and material properties related to flexure and shear in beams and framed systems; vector mechanics with application to analysis of trusses, catenaries, and arches; diagrammatic analysis of beams for bending moment, shear, and deflection; and the study of structural framing systems for vertical and lateral loads.

### Objectives

Students are introduced to the fundamentals of statics and mechanics, as well as the behavior of structural materials and simple elements and systems subjected to gravity and lateral loads. Diagramming of force distribution in beams as well as topics of stress, strain and stability are covered. Through classroom demonstrations as well as physical construction and testing, aspects of strength and stability of structural systems are examined.

### Organization

The course is lecture based, and the concepts and procedures are taught in this context with additional homework problems solved by the students. Weekly recitations provide opportunity for small demonstration labs as well as student-instructor interaction. A group design and construction project (load testing of a bridge) offers a chance to test out concepts covered in the class. Computer facilities, including software, are available for supporting computations. A course web site is used to post all lectures, homework problems, as well as other information for the class (<http://www.structures1.tcaup.umich.edu/>). Weekly topic quizzes will also be posted on the course Canvas site.

### Evaluation

Evaluation is based on an accumulated total number of points. Points are earned based on performance in all course activities – lecture quizzes, topic quizzes (Canvas), homework problems, recitation labs, and the bridge project. Grades are based on the total number of points achieved during the semester.

24 lecture quizzes, 10pts each	240
14 topic quizzes, 20pts each	280
14 homework problems, 5 pts / question	805
bridge testing project	250
12 recitation labs, 20 pts each	240
<b>TOTAL</b>	<b>1815</b>

# Schedule

Architecture 314

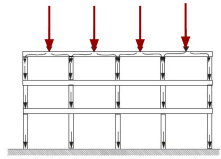
Fall 2024

## ARCHITECTURAL STRUCTURES I (3) Lecture and Homework Schedule

DATES	TOPICS	Reading (Onouye 4 <sup>th</sup> ed.)	HW PROBLEMS
AUG 26	Course Intro: Overview of Forces		Structures video TA 645.S78
AUG 28	Vertical Loads	Ch. 1: pp. 1-14	
AUG 30	Lateral Loads Topic Quiz 1	Ch. 1: pp. 1-14	1. Dead Load Calculation (9.1)
SEP 2	<b>LABOR DAY ***** NO CLASS *****</b>	<b>LABOR DAY ***** NO CLASS *****</b>	<b>LABOR DAY ***** NO CLASS *****</b>
SEP 4	Force Systems: Vector Addition	Ch. 2.1: pp. 15-22 Ch. 2.2: pp. 23-41	2. Three Vector Addition (9.8)
SEP 6	Recitation 1. Adding Forces Topic Quiz 2		3. Moment of a Force (9.13) 4. Parallel Force Systems (9.15)
SEP 9	Force Systems: Moment of a Force	Ch. 2.3: pp.42-60 Ch.3.6: pp.175-184	
SEP 11	Force Systems: Equilibrium	Ch. 2.4 – 2.6: pp. 61-95	
SEP 13	Recitation 2. Moment of a Force Topic Quiz 3		5. Equilibrium of Rigid Bodies (9.22)
SEP 16	Equilibrium of Rigid Bodies	Ch. 3.2: pp. 111-118	
SEP 18	Cable Systems	Ch. 3.1: pp. 96-110	
SEP 20	Recitation 3. Equilibrium Topic Quiz 4		6. Cable Systems (9.29)
SEP 23	Catenary Arches and Shells + Bridge Project Introduction	Ch. 3.3: pp. 119-127	
SEP 25	Plane Trusses (by Joints)		
SEP 27	Recitation 4. Truss Stability Topic Quiz 5		7. Truss Systems (10.6)
SEP 30	Building Big – Bridges (video)		
OCT 2	Plane Trusses (by Sections)	Ch. 3.3: pp. 128-152 (interim bridge report due - 10.4)	
OCT 4	Recitation Topic Quiz 6		
OCT 7	Plane Trusses (by Graphic Statics)	Ch. 3.4: pp. 153-163	
OCT 9	Pinned Frames		
OCT 11	Recitation 5. Graphic Statics Topic Quiz 7		
OCT 14	<b>***** FALL STUDY BREAK ***** FALL STUDY BREAK ***** FALL STUDY BREAK ***** FALL STUDY BREAK *****</b>		
OCT 16	Three Hinged Arches	Ch. 3.5: pp. 164-174	
OCT 18	Recitation 6. Three Hinged Arches Topic Quiz 8		8. Three Hinged Arches (10.20)
OCT 21	Load Tracing & Floor Systems	Ch. 4.1: pp. 195-230	
OCT 23	Lateral Stability	Ch. 4.2: pp. 231-250	
OCT 25	Recitation 7. Lateral Stability Topic Quiz 9		9. Floor Systems (10.27)
OCT 28	Stress and Strain	Ch. 5.1: pp. 251-266	
OCT 30	Elasticity and Deformation	Ch. 5.2-5.4: pp. 267-293	
NOV 1	Recitation 8. Elasticity Topic Quiz 10		10. Elastic Deformation (11.3)
NOV 4	<b>***** Bridge Testing ***** Bridge Testing ***** Bridge Testing ***** Bridge Testing ***** Bridge Testing *****</b>		
NOV 6	Cross-Sectional Properties	Ch. 6.1 - 6.4: pp. 300-331	
NOV 8	Recitation 9. Moment of Inertia Topic Quiz 11		11. Moment of Inertia (11.10)
NOV 11	Shear and Bending Forces pt1	Ch. 7.1-7.3: pp. 332-345	
NOV 13	Shear and Bending Forces pt2	Ch. 7.4-7.5: pp. 346-364	
NOV 15	Recitation 10. Moment Diagrams Topic Quiz 12		

# Vertical and Lateral Load

## Types of Loads



Gravity Loads  
(Vertical to the structure)

Live Load

Transient and moving.  
Eg. Occupancy,  
Furniture,  
Storage.

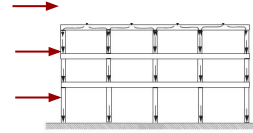
Dead Load

Static.  
Eg. Self weight  
of the structure,  
partition wall,  
fixed furniture.

Snow Load

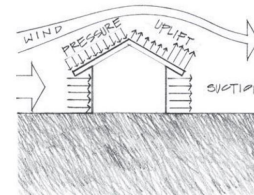
Accumulation of  
Snow/Ice.  
Determined by  
zone map.

Lateral Loads  
(Horizontal to the structure)



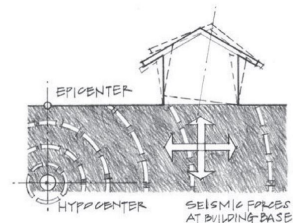
Wind Load

Pressure exerted  
by the wind.



Earthquake Load

Structure is  
shaken by the  
earthquake.



# Problem Set 01

## 1. Dead Load Calculation

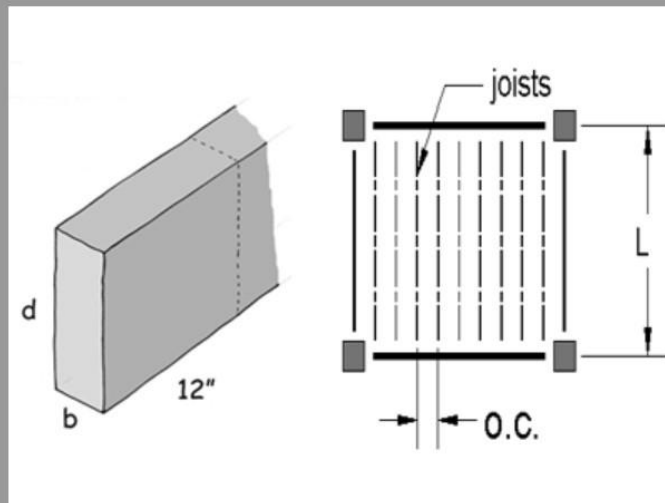
For the given member cross-section and length, find the DL in PLF of the joist member, total pounds of the member, and PSF DL of the joist on the floor.

DATASET: 1

-2-

-3-

Width, b	3.5 IN
Depth, d	7.5 IN
Length, L	6 FT
On center spacing	12 IN
Species class	Mixed Southern Pine
Density	33 PCF



#	Question	Your Response	Correct Answer	Score
1	The cross-sectional area: A	26.25 IN <sup>2</sup>	26.25 IN <sup>2</sup>	5
2	Dead load of joist section	6.0156 PLF	6.01562 PLF	5
3	Dead load of whole joist member	36.0938 LBS	36.0938 LBS	5
4	Dead load of joists on floor	6.02 PSF	6.01562 PSF	5

Current Score: 20 / 20

# Formulas

- Cross sectional Area,  $a \text{ (in}^2\text{)} = b \times d \text{ (in)}$
- Dead Load of joist section,  $DL \text{ (plf)} = \text{Area (ft}^2\text{)} \times \text{Density (pcf)}$
- Dead load of whole joist member (lbs) =  $DL \text{ (plf)} \times L \text{ (ft)}$
- Dead load of joist on the floor (psf) =  $DL \text{ (plf)} / oc \text{ (ft)}$

## Given data and Units

- Width,  $b \text{ (in)} = 3.5''$
- Depth,  $d \text{ (in)} = 7.5''$
- Length,  $L \text{ (ft)} = 6'$
- On center spacing (in) =  $12''$
- Density,  $D \text{ (pcf)} = 33$

## Questions

Q1. Cross sectional Area ( $a$ ) =  $b \times d = 3.5 \times 7.5 = 26.25 \text{ in}^2$

Q2. Dead Load of joist section (DL)

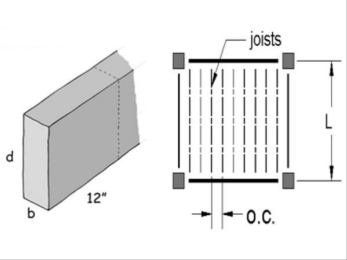
- Convert area to  $\text{ft}^2 = 26.25/144 = 0.1823 \text{ ft}^2$
- Dead Load of joist section =  $a \times D = 0.1823 \times 33 = 6.0156 \text{ plf}$

Q3. Dead load of whole joist member =  $DL \times L = 6.0156 \times 6 = 36.0938 \text{ lbs}$

Q4. Dead load of joist on the floor =  $DL \times oc = 6.0156 \text{ psf}$

1. Dead Load Calculation

For the given member cross-section and length, find the DL in PLF of the joist member, total pounds of the member, and PSF DL of the joist on the floor.



DATASET: 1    -2-    -3-

Width, b	3.5 IN
Depth, d	7.5 IN
Length, L	6 FT
On center spacing	12 IN
Species class	Mixed Southern Pine
Density	33 PCF

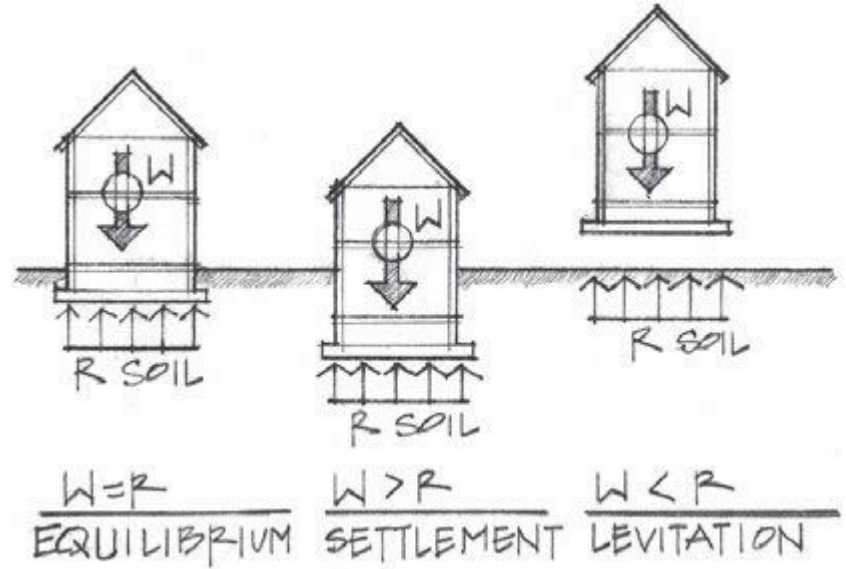
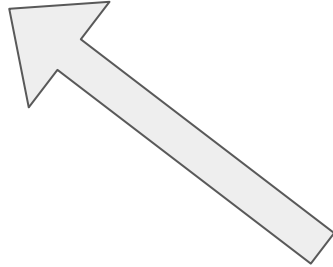
#	Question	Your Response	Correct Answer	Score
1	The cross-sectional area: A	26.25 IN^2	26.25 IN^2	5
2	Dead load of joist section	6.0156 PLF	6.01562 PLF	5
3	Dead load of whole joist member	36.0938 LBS	36.0938 LBS	5
4	Dead load of joists on floor	6.02 PSF	6.01562 PSF	5

Current Score: 20 / 20

# Statics and Vectors Addition

Vector is characterized by:

- Point of application
- Magnitude (lbs)
- Direction



Force Systems:

- Collinear
- Coplanar
- Coplanar, Parallel
- Coplanar, Concurrent
- Non-coplanar, Parallel
- Non-coplanar, Concurrent
- Non-coplanar, Non-concurrent

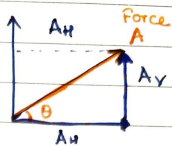
whenever a body A exerts a force on another body B, body B will resist with an equal magnitude but in the opposite direction.

# Formulas

# Horizontal component:

$$\cos \theta = \frac{\text{adjacent}}{\text{hypo}} = \frac{A_H}{A}$$

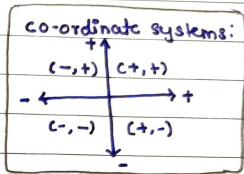
$$A_H = \cos \theta \times A$$



# Vertical component:

$$\sin \theta = \frac{\text{opposite}}{\text{hypo}} = \frac{A_V}{A}$$

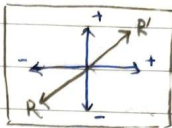
$$A_V = \sin \theta \times A$$



# Sum of horizontal & vertical components:

$$F_{Rx} = A_H + B_H + C_H$$

$$F_{Ry} = A_V + B_V + C_V$$



[Be careful of +ve & -ve sign]

[Draw the resultant force accordingly]

# Absolute value: (Resultant of the Forces)

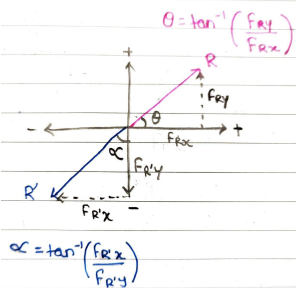
$$F_R = \sqrt{F_{Rx}^2 + F_{Ry}^2}$$

# Angle of the resultant in degrees from +ve x axis counter clockwise.

$$\tan \theta = \frac{\sin \theta}{\cos \theta} = \frac{\text{opp/hypo}}{\text{adj/hypo}} = \frac{\text{opposite}}{\text{adjacent}}$$

[consider the resultant force diag. from #7 & #4]

$$\theta = \tan^{-1} \left( \frac{\text{opposite}}{\text{adjacent}} \right)$$



$$\alpha = \tan^{-1} \left( \frac{F_{Ry}}{F_{Rx}} \right)$$

# Example:

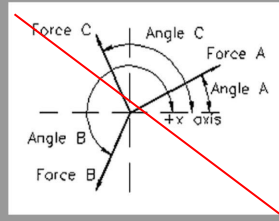
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Redraw the figure according to given data as it does not align

2. Three Vector Addition

Find the horizontal and vertical components of each of the three forces shown. Then find the resultant of all forces and the angle measured counter-clockwise from the + x-axis.

DATASET: 2

Force A	88 LBS
Angle A	18 DEGREES
Force B	48 LBS
Angle B	146 DEGREES
Force C	31 LBS
Angle C	183 DEGREES



#	Question	Your Response	Correct Answer	Score
1	Horizontal component of Force A (+ to right: - to left)	83.693 LBS	83.693 LBS	5
2	Vertical component of Force A (+ upward: - downward)	27.1934 LBS	27.1935 LBS	5
3	Horizontal component of Force B (+ to right: - to left)	-39.7938 LBS	-39.7938 LBS	5
4	Vertical component of Force B (+ upward: - downward)	26.8413 LBS	26.8413 LBS	5
5	Horizontal component of Force C (+ to right: - to left)	-30.9575 LBS	-30.9575 LBS	5
6	Vertical component of Force C (+ upward: - downward)	-1.6224 LBS	-1.62241 LBS	5
7	Sum of horizontal components (+ to right: - to left)	12.9417 LBS	12.9417 LBS	5
8	Sum of vertical components (+ upward: - downward)	52.4123 LBS	52.4123 LBS	5
9	Resultant of Forces A + B + C (absolute value)	53.9864 LBS	53.9865 LBS	5
10	Angle of the Resultant in DEGREES from + x axis counterclockwise	76.1299 DEGREES	76.13 DEGREES	5

Current Score: 50 / 50

Problem Menu

Logout

# Problem Set 02

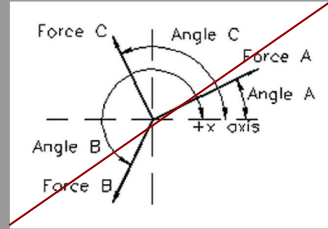
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## 2. Three Vector Addition

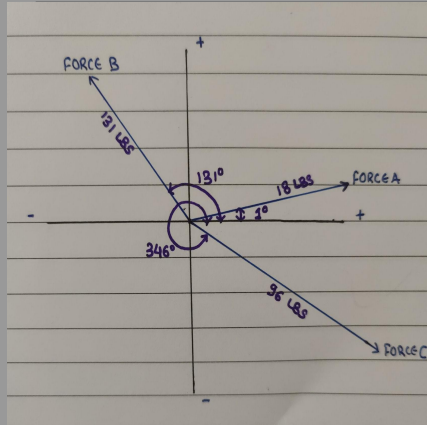
Find the horizontal and vertical components of each of the three forces shown. Then find the resultant of all forces and the angle measured counter-clockwise from the + x-axis.

DATASET: 1    -2-    -3-

Force A	18 LBS
Angle A	1 DEGREES
Force B	9 LBS
Angle B	131 DEGREES
Force C	96 LBS
Angle C	346 DEGREES



- # Question
- Horizontal component of Force A (+ to right: - to left)
  - Vertical component of Force A (+ upward: - downward)
  - Horizontal component of Force B (+ to right: - to left)
  - Vertical component of Force B (+ upward: - downward)
  - Horizontal component of Force C (+ to right: - to left)
  - Vertical component of Force C (+ upward: - downward)
  - Sum of horizontal components (+ to right: - to left)
  - Sum of vertical components (+ upward: - downward)
  - Resultant of Forces A + B + C (absolute value)
  - Angle of the Resultant in DEGREES from + x axis counterclockwise



Problem Menu

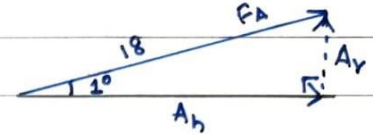
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## Q1 Q2 Horizontal and vertical components of Force A

A

$$\sin \theta = \frac{\text{opposite}}{\text{hypot.}}$$

$$\sin(1^\circ) = \frac{A_v}{18}$$



$$A_v = \sin(1^\circ) \times 18 = 0.3141 \text{ LBS}$$

# Vertical component of force A = 0.3141 LBS.

$$\cos \theta = \frac{\text{adjacent}}{\text{hypot.}}$$

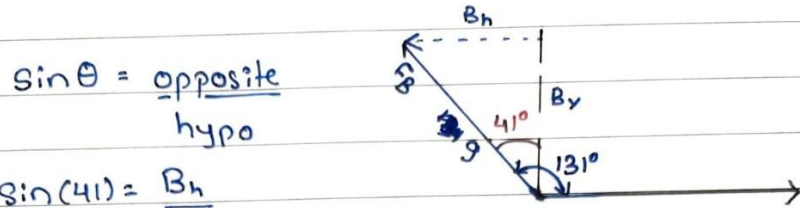
$$\cos(1^\circ) = \frac{A_h}{18}$$

$$A_h = \cos(1^\circ) \times 18 = 17.9973 \text{ LBS}$$

# Horizontal component of force A = 17.9973 LBS.

## Problem Set 02

Q3 Q4 Horizontal and vertical components of Force B



$$\sin \theta = \frac{\text{opposite}}{\text{hypo}}$$

$$\sin(41) = \frac{B_h}{9}$$

$$-5.9045$$

$$B_h = \sin(41) \times 9 = -5.9045 \text{ LBS}$$

# Horizontal component of force B = -5.9045

$$\cos \theta = \frac{\text{adjacent}}{\text{hypo}}$$

$$\cos(41) = \frac{B_v}{9}$$

$$6.7924$$

$$B_v = \cos(41) \times 9 = 6.7924 \text{ LBS}$$

# Vertical component of force B = 6.7924

Q5 Q6 Horizontal and vertical components of Force C

$$\sin \theta = \frac{\text{opposite}}{\text{hypo}}$$

$$\sin(14) = \frac{C_v}{96}$$

$$C_v = \sin(14) \times 96 = -23.2245 \text{ LBS}$$

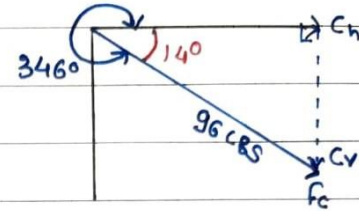
# Vertical component of force C = -23.2245 LBS

$$\cos \theta = \frac{\text{adjacent}}{\text{hypo}}$$

$$\cos(14) = \frac{C_h}{96}$$

$$C_h = \cos(14) \times 96 = 93.1484 \text{ LBS}$$

# Horizontal component of force C = 93.1484 LBS



## Problem Set 02

### Q7 Sum of the horizontal components

# Sum of horizontal components ( $F_{Rx}$ )

$$\begin{aligned}F_{Rx} &= A_h + B_h + C_h \\ &= 17.9973 + (-5.9045) + (93.1484) \\ &= 105.2412 \text{ LBS}\end{aligned}$$

### Q8 Sum of the vertical components

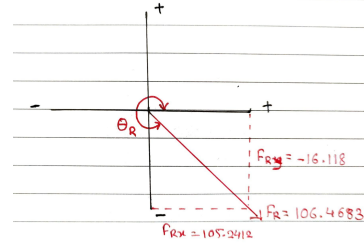
# Sum of the vertical component ( $F_{Ry}$ )

$$\begin{aligned}F_{Ry} &= A_v + B_v + C_v \\ &= 0.3141 + 6.7924 + (-23.2245) \\ &= -16.118 \text{ LBS.}\end{aligned}$$

### Q9 Absolute Value- Resultant of Forces A+B+C

# Resultant of Force A+B+C (absolute value)

$$\begin{aligned}F_R &= \sqrt{F_{Rx}^2 + F_{Ry}^2} = \sqrt{(105.2412)^2 + (-16.118)^2} \\ &= \sqrt{11335.5} = 106.4683 \text{ LBS}\end{aligned}$$



### Q10 Angle of resultant from degree (from +x axis counterclockwise)

# Angle of the resultant in Degrees.

$$\begin{aligned}\theta_R &= \tan^{-1}\left(\frac{F_{Ry}}{F_{Rx}}\right) = \tan^{-1}\left(\frac{-16.118}{105.2412}\right) \\ &= 8.7074.\end{aligned}$$

$$\theta_R = 360 - 8.7074 = 351.2926^\circ$$

# Recitation- Lab 01

Structures I

Arch 314

Name 1 \_\_\_\_\_

Name 2 \_\_\_\_\_

## Adding Forces

### Description

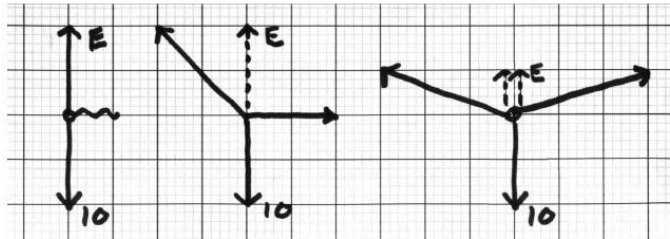
This project is intended to give a sense how forces combine in a system of equilibrium. A selection of 3 force equilibrium systems are modeled both physically and graphically to verify hand calculations.

### Goals

- To model two component forces of an equilibrant in tension using a physical model.
- To show the vector addition of the same 2 forces to find the resultant
- To make hand calculations of the same vector addition.

### Procedure

- Using a piece of string with some weight tied to the middle; hold the two string ends at  $0^\circ$  and  $90^\circ$  (horizontal and vertical). Observe that the horizontal is slack (no force in the string). Your hand on the vertical string is the equilibrant force to the force of gravity acting on the weight.
- Move the vertical string so one string is at  $45^\circ$  and the other at  $0^\circ$  (horizontal).
- Make a scaled sketch of equilibrant force (opposite to the weight) and its 2 component forces (the two strings in your hands). Scale the force not the string. Assume the weight to be 10 units. Scale the forces on the graph paper and estimate the force magnitude of each of the two component forces.
- Use either trigonometry or similar triangles to calculate the forces in the strings. Compare your results with the graphic result.
- Try another variation like the third figure below.
- Try to pull the 2 strings horizontal (don't break the string). Observe that there tends to be a small sag in the string even when pulled fairly taut.



Structures I  
Arch 314

Name(s):

