SCHOOL OF ARCHITECTURE, BUILDING & DESIGN
Research Unit for Modern Architecture Studies in Southeast Asia
Bachelor of Science (Honours) (Architecture)

Building Structures (ARC 2523)
Prerequisite: Building Construction 2 (ARC2213)

Project 1
Fettuccine Truss Bridge

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1.0 Introduction

The aim of this project is to develop an understanding of tension and comprehensive strength of construction materials by understanding distribution on force in a truss.
In order to achieve that, we need to conduct a research of precedent study on a tuss bridge that we choose to analyze about the connections, arrangements, orientations of the members as well as the strength of the members. After the analysis of the precedent study, then only we are required to design and construt a truss brigde that made out of fettuccini.

The Requirements of this bridge is to not exceed the maximum weight of 200g and it must having 750mm clear span. The bridge will be tested to fail and at the same time we were required to analyze the reason of its failure and calculate the efficiency.

1.2 Objective

The objective of this project is to develop more understanding of tension and compressive strength of construction materials as well an understanding of force distribution in a truss. We will also be able to analyze and calculate the efficiency of fettuccini in terms of tension and compression strength. We also be able to identify the strength of the critical members by adopting appropriate.

1.3 Learning Outcomes

At the end of the project, we will be able to evaluate, explore and improve attributes of construction materials. We did explore and apply understanding of load distribution in a truss. We also be able to evaluate and identify tension and compression members in a truss structure. Lastly we able to explore different arrangement of members in a truss structure.

2.0 Methodology

2.1 Precedent Study

We have conduct a research for a truss bridge and study on its connections, arrangement of members and orientation of each members. The Fettuccine Bridge will be design and constructed based on the information of the precedent study.

2.2 Materials testing & Equipment Preparation

Phase 1: Strength of material
Understanding the properties of the fettuccine is important in order to build one bridge that can carry maximum load. For the tensile strength in the fettuccine is considerable low when compare to aluminium which has the same amount of stiffness to the fettuccine.

Phase 2: Adhesive
Choosing the right type of adhesive is important as it plays a huge role in this assignment. As there are many types of adhesive in the market that each has their own function and characteristics. Not only the type of adhesive is important but the brand of adhesive is important as well, for different brand has different quality and choosing one that suits constructing the fettuccine bridge is primary.

Phase 3: Model making
To ensure precision in our model making. Drawings are drawn in 1:1 scale and plotted out to ensure precision and ease our process. In order to strengthen our bridge as much as possible, each fettuccine is marked individually as each has their own location of placement and length, and are glued accordance.

Phase 4:
Finished models are being tested after placing aside to allow the adhesive to sit on the model. By placing weight on the middle of intermediate member to ensure that load is

evenly distributed. All these are being recorded to allow us to fix and analysis our bridge.

2.3 Model Making & Design Development

The fettuccini is designed by hand drawn, so the fettuccini were follow up the drawing on paper according to scale for model making.

Requirements

- To have a clear span of 750mm
- Not exceeding the weight of 200g
- Only material allowed is fettuccine and adhesive
- The bridge will tested to fail
- Workmanship is put to consideration as part of aesthetic value

2.4 Structural Analysis

Structural analysis is a determination of the effects of load on the Fettuccini Bridge and its members by calculation.

2.5 Bridge's Eficiency Calculation

Efficiency of the bridge is calculated after it is tested to fail by using a formula:

$$\text{Efficiency, } E = \frac{(\text{Maximum load})}{\text{Mass of bridge}}$$

Introduction of Truss

Trusses are one of the most widely adopted structural designs, many times being utilized as the structural solution of choice for bridges, roofs, cranes and so on.

Figure 1.1 Examples of structures composed of truss such as bridge (left), tower crane (middle) and roof truss (right).

A truss is defined as a structure built up of three or more members which are normally considered as being pinned or hinged at the various joints. Any loads which are applied to the truss are usually transmitted to the joints, so that individual members are in pure tension or compression. Tension is a force that acts to stretch or pull an object. Compression is a force that acts to squeeze or push an object.

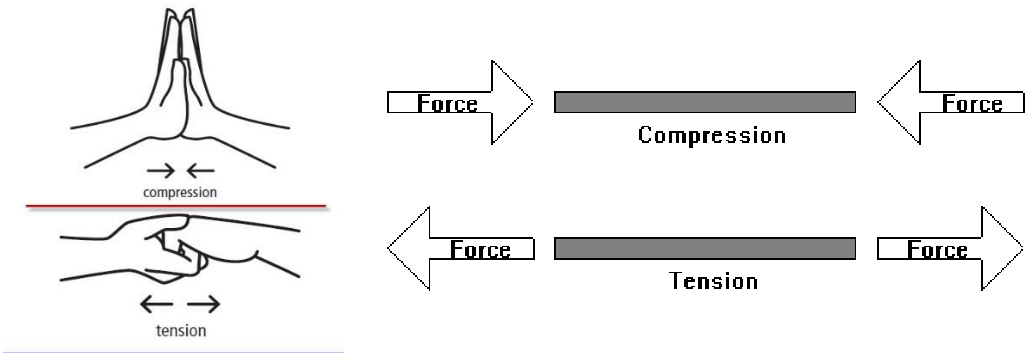


Figure 1.2 Compression and tension forces acting on hands.

Compression and tension are present in all bridges, and as illustrated, they are both capable of damaging part of the bridge as varying load weights and other forces act on the structure. It's the job of the bridge design to handle these forces without buckling or snapping. Buckling occurs when compression overcomes an object's ability to endure that force. Snapping is what happens when tension surpasses an object's ability to handle the lengthening force.

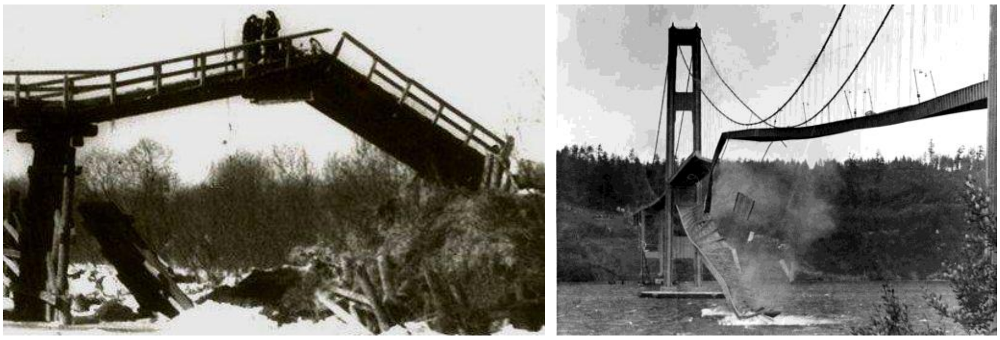


Figure 1.3 Examples of truss bridge failures such as buckling (left) and snapping (right).

The best way to deal with these powerful forces is to either dissipate them or transfer them. With dissipation, the design allows the force to be spread out evenly over a greater area, so that no one spot bears the concentrated brunt of it. In another word, the forces acting at each end of a member must be equal to avoid any failures.

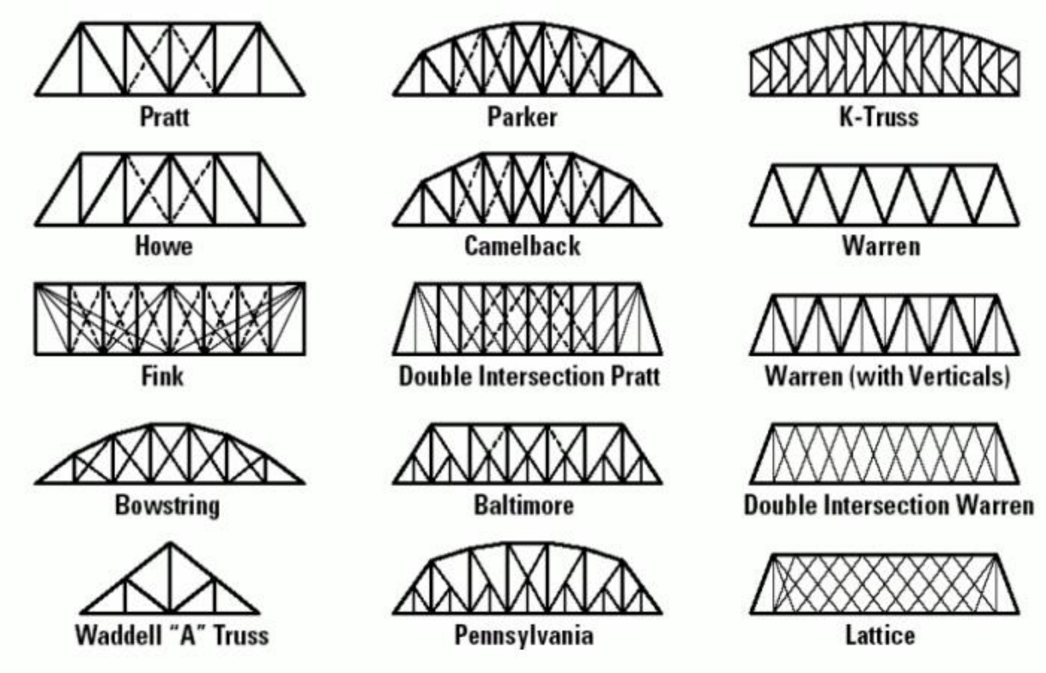
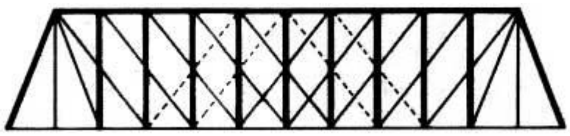


Figure 1.4 : Example of Truss bridge

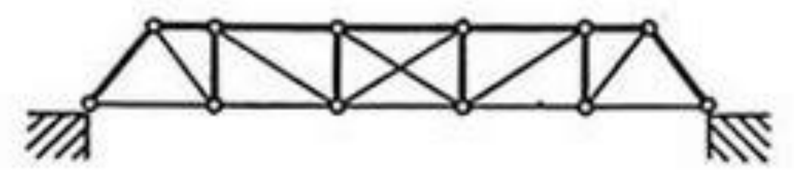
Introduction of Pratt Truss

The Pratt truss is identified by a simple web arrangement of diagonals in tension and verticals in compression, except for the hip verticals immediately adjacent to the inclined end posts of the bridge. It was first developed in 1844 by Thomas Pratt and his architect father, Caleb Pratt. The Pratt truss inspired a large number of variations and modified subtypes during the nineteenth and early twentieth centuries. Major subtypes of the Pratt design included:

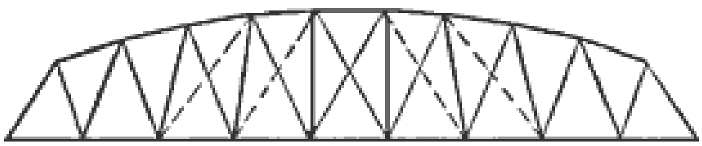
1. Double Intersection Pratt Truss (Whipple, Whipple-Murphy, or Linville)



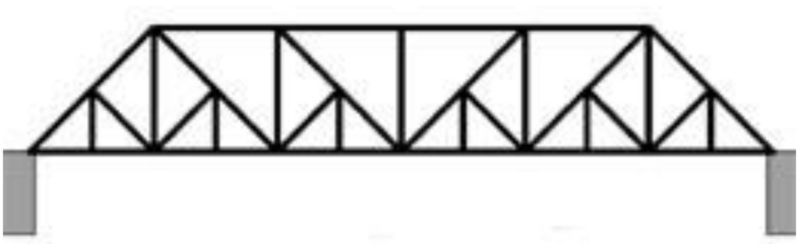
2. Pratt Half-Hip Truss



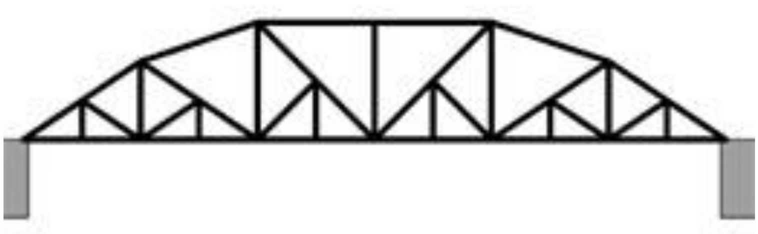
3. Parker Truss



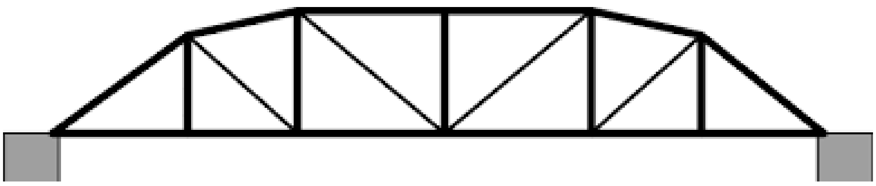
4. Baltimore (Petit) Truss



5. Pennsylvania (Petit) Truss



6. Camelback Truss



3.0 Precedent Studies

The Rio Puerco Bridge

The Rio Puerco Bridge is a Parker Through truss bridge located on historic U.S. Route 66, crossing the Rio Puerco, that was built in 1933. It is located approximately 19 miles (30 km) west of Albuquerque, New Mexico, United States. The bridge consists of 10 panels measuring 25 feet in length, each with its top cord at a different angle, as is characteristic of Parker truss design bridges. The 25-foot wide deck is concrete with an asphalt surface and rests on steel stringers. This design was selected partially because it was commonly used during the late-1920s and 30s, but also because it was particularly suitable for this bridge, which needed to withstand a river capable of massive flooding that had washed away previous bridges along the Rio Puerco.

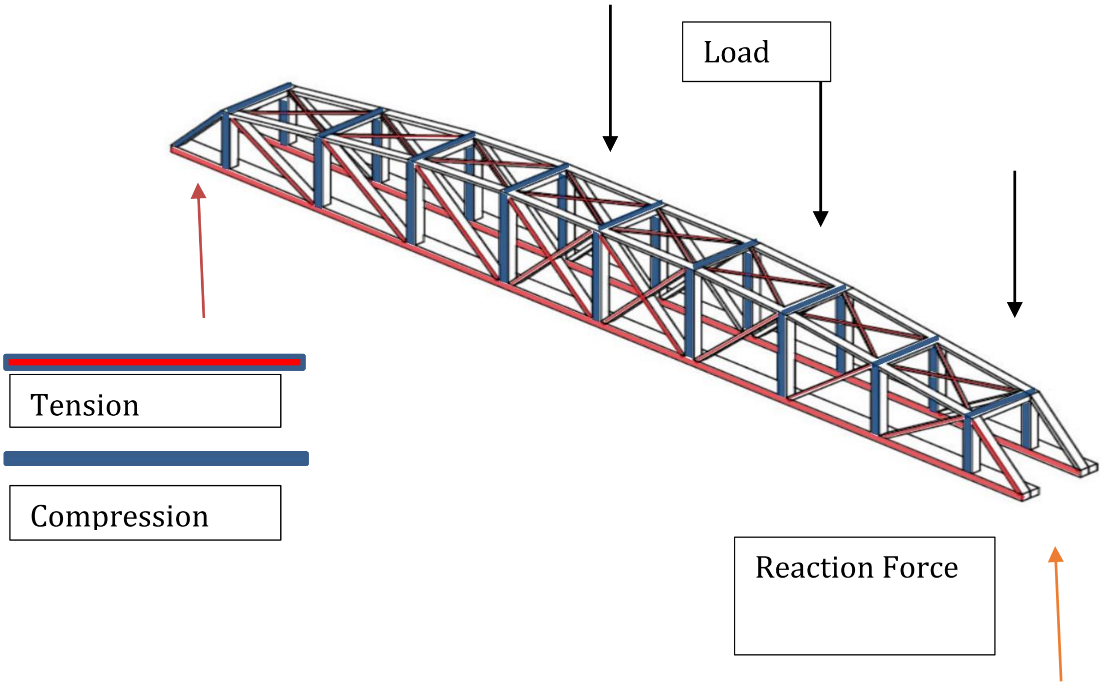
In 1957, the truss was remodeled, and the lower portal struts were removed and replaced by lighter struts that were inserted above to create a higher clearance. Metal guardrails were added to protect the truss members. This bridge served motorists on Route 66 for many years, and when I-40 was completed, the Rio Puerco Bridge became part of a frontage road across the Rio Puerco.

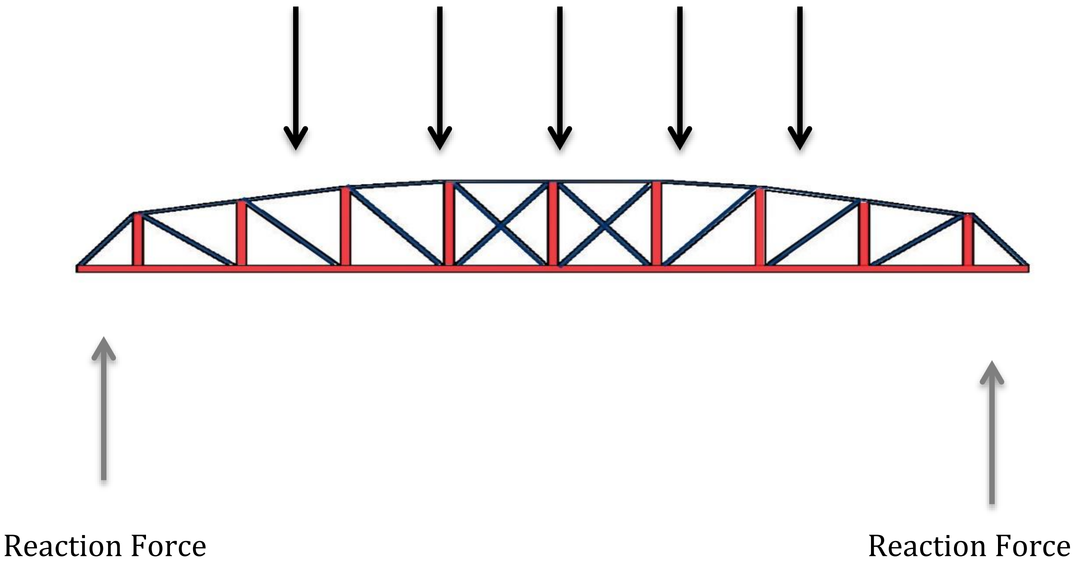
The structure was listed in the National Register of Historic Places in 1997. In 1999, the New Mexico State Highway and Transportation Department replaced it but preserved the historic bridge. Though currently closed to car traffic, the old bridge is open for people to walk across, allowing visitors a glimpse of the old Highway 66 slowly curving and dipping as it disappears into the vast New Mexico desert.

Interior Details

Exterior details

Pratt Truss


Load
Tension
Compression
Reaction Force


Reaction Force
Reaction Force

Load Distribution

When a point load is hung from the middle of a Pratt truss bridge, the members of the outer frame (excluding the all diagonal bracings) that span the 2 foundations are seen to be in compression. They support the point load. When the load exceeds the breaking point of the steel structure, the whole bridge will then give way. In order to strengthen the bridge, diagonal bracings are fitted within the steel frame. In this case, the Pratt truss bridge is fitted with diagonal and also 'X' shaped bracings at the middle to provide rigidity to the bridge which keeps it from moving. The bracings are in tension which also holds the lower chord members.

The members in tension are the diagonal members which all points towards the centre of the bridge, where the load is applied. When forces are pulling the bridge and its members downwards from the centre, these members help to balance the load by pulling in two opposite directions, half to the right and half to the left. The members at the top are longer compared to the ones at the bottom, because the force is pulling from the bottom, therefore the members at the top has to be longer in order to withstand the pulling force from the bottom.

The members in compression are the vertical and horizontal members that hold and support the bridge. The vertical members function to support the diagonal members and the horizontal members function to hold the vertical members. The force pulling from the bottom is distributed along the bridge according to the length of the vertical members, with the centre vertical member being the longest to withstand the direct pull from the centre of the bridge.

4. Materials & Equipment
4.1 Fettuccine (Main material)

Exploration has been made to 4 different types of fettuccini to determine their strength and suitability for model making.

Type of Fettuccini	Observation & Description	Efficiency
1. Kimball 	1) Flat profile 2) Thin 3) Light 4) Fragile	1
2. Arbell 	1) Concave profile 2) Heavy 3) Thin 4) Fragile	2
3. Prego 	1) Flat Profile 2) Light 3) Fragile 4) Thin	3
4. San Remo 	1) Concave profile 2) Thick 3) Heavy 4) Strong	4

4.2 Glue (Adhesive Material)

Exploration on several types of glue to tested on fettuccini to determine which one is the most suitable as the adhesive in terms of Efficiency for model making.

Type of Glue	Observations & Description	Efficiency
1) White Glue  	1) Water based 2) Fettuccini softened by the glue 3) Glue joints take forever to dry 4) Once dry, joints are not very strong	1
2) Model airplane glue  	1) Dries relatively quickly 2) Slightly flexible when dry 3) Glue joints should be rigid	2
3)hot glue gun 	1) Easiest to use 2) Joint are far too flexible	3
4)Epoxy  	1) Creates rigid joints 2) Messy 3) Requires careful mixing 4) Very slow to dry, take long time.	4
5) Uhu Super Glue  	1) Easy to use 2) Dry very fast 3) High efficiency 4) Cracked joint after dried for few days	5

4.3 Equipment

S Hook

Bucket

S hook used to hang the load with the aid of basket on Fettuccini Bridge. Hence all the force applied on one point of the bridge.

Weight

Water Bottle

Weight and water bottle act as the load to test the strength of Fettuccini Bridge.

Weighing Machine

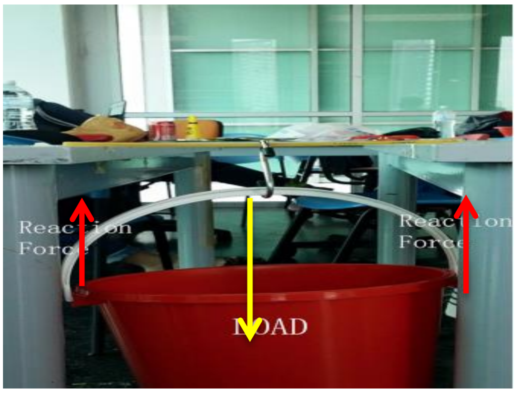
Weighing machine used to weigh the mass of fettuccini bridge to ensure that it is not overweight / exceed the maximum weight of 200grams.

4.4 Strength Testing

Strength testing on 2 types of fettuccini that we choose according to the efficiency. Fettuccini also were tested by having 6 layers.


San Remo

Prego



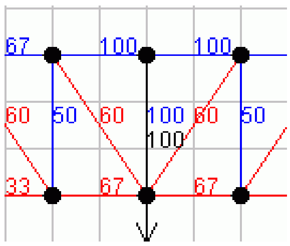
Brand	Type of glue	100g	150g	200g	250g	300g	350g	400g	450g
Prego	Super Glue	✓	✓	✓	✓	✗	✗	✗	✗
San Remo	Super Glue	✓	✓	✓	✓	✓	✓	✓	✗
San Remo	Epoxy	✓	✓	✓	✓	✓	✓	✗	✗
Prego	Epoxy	✓	✓	✓	✓	✓	✗	✗	✗

Table 4.4.1 Above shows the analysis of strength on 2 different types of Fettuccini and 2 different types of glue.

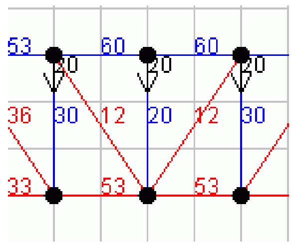
How the forces are spread out

Pratt Truss

Here are two diagrams showing how the forces are spread out when the Pratt Truss is under a load. The first shows the load being applied across the entire top of the bridge. The second shows a localized load in the center of the bridge. In both cases the total load = 100. Therefore, you can take the numbers as a percentage of the total load.



Pratt Truss With Centered Load



Pratt Truss with Spread Load

These diagrams bring up several interesting things. Notice that the two end diagonal members do not change. Also, there is little change on the bottom chord between the two pictures. However, there is drastic changes on the internal truss members. The centered load dramatically increases the amount of force that is applied to the internal members of the bridge. Also, the forces are increased on the top chord of the centered loaded bridge.

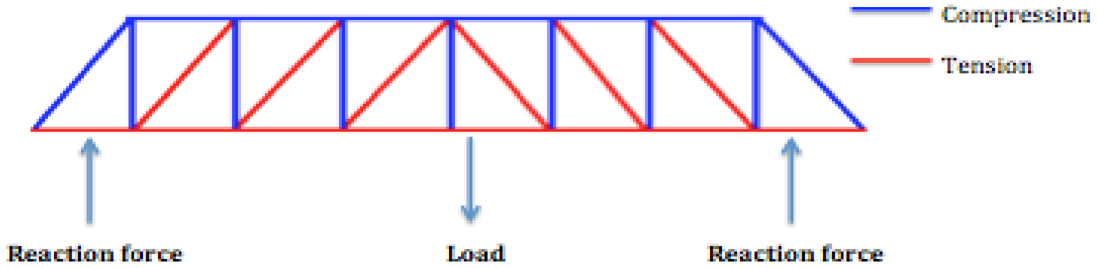
This seemingly insignificant change in how the bridge is loaded makes a big difference in how your model bridge will perform. If you have the ability to change and set how your bridge is loaded, I'd shoot for spreading the load across the entire span. This pretty much goes for any model bridge design, not just the Pratt Truss.

5 Model Making & Design Development

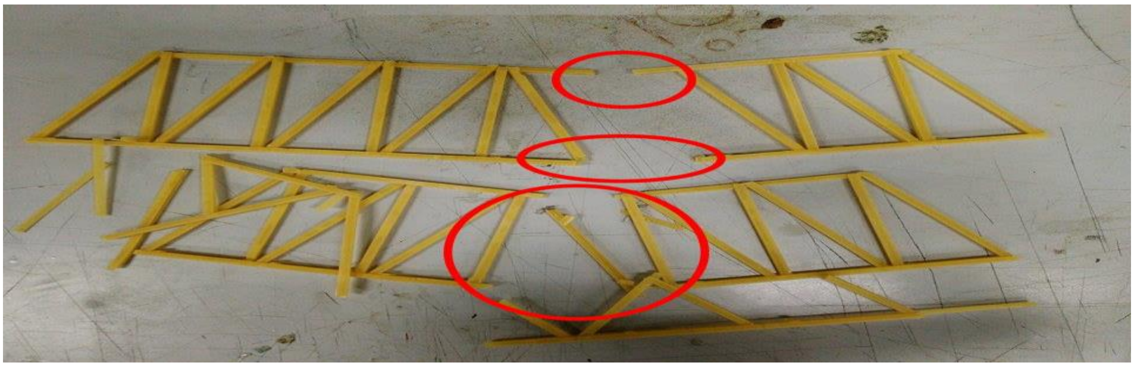
Requirements for fettuccini bridge:

a) 350mm clear span bridge
b) Maximum weight of 200g
c) Only fettuccini can be used
d) Bridge will be tested until break.

Fettuccini Bridge Design 1



Howe Truss



Total length = 400mm
Clear span = 350mm
Efficiency = 30.77%

Weight of bridge = 130g
Load sustained = 2kg

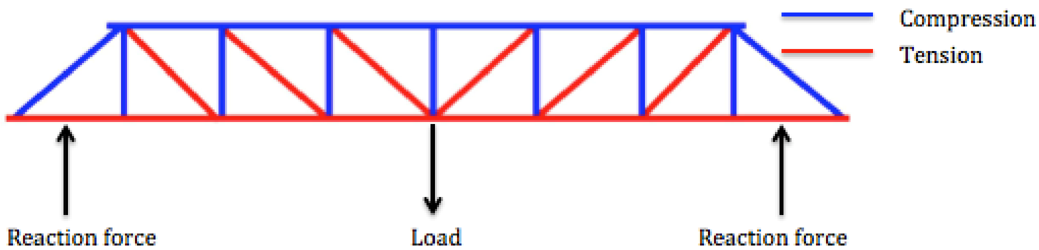
Problem: Poor connection between joints

After analyzing the structure of a Howe truss, a Howe truss used for the construction of a bridge model is not the wisest choice in terms of material strength. The upper chords and the intermediate posts which are compression members highlighted in blue colour where else the tension are all highlighted red. There is a majority of members of the truss that are under compression compared to the ones under tension. This serves as a disadvantage because fettuccine has strong tension properties. The glue which was supposed to hold the joints together broke off which caused the upper chord members to fail in support, causing the truss to snap.

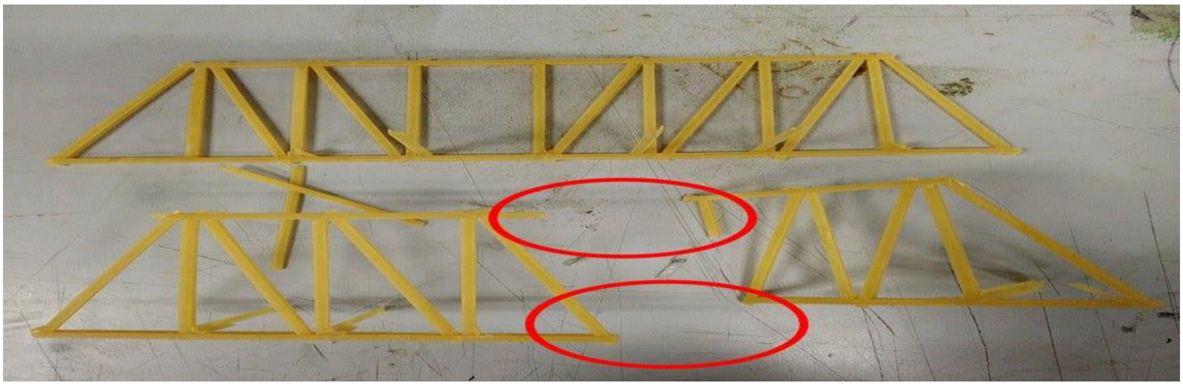
Solution:

1. Ensure joints are connected properly.
2. Use adhesive to connect properly.
3. Apply gusset plate theory.

Fettuccini Bridge Design 2



Pratt Truss



Clear span = 350mm Load sustained = 2.3kg

Efficiency = 44.08%

Problem: Load is not distributed to the main component

The idea structure is basically following the classic Pratt truss design. We also design the bridge dimension into a cube shape in every part of the beam column. After testing the model, the whole bridge structure is still remaining good condition, only the supporting component park broke down. So we decided to change the supporting component part to an I-beam structure and having the load test on the same model again. We found out that the I-beam structure help a lot on the model efficiency.

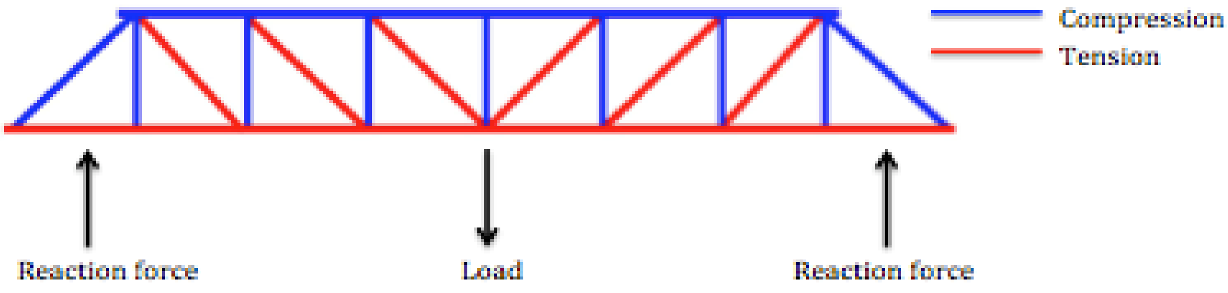
Solution :

1. Making sure the breaking point location of fettuccine is evenly spread out for the base.
2. Strengthen the vertical joints
3. Extending the end of the base
4. Reduce the weight of the bridge by reducing the horizontal joints to four layer

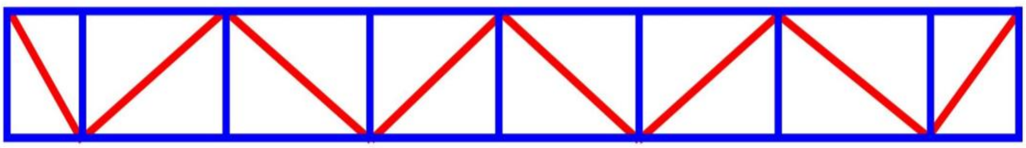
6. Model Making of Pratt truss

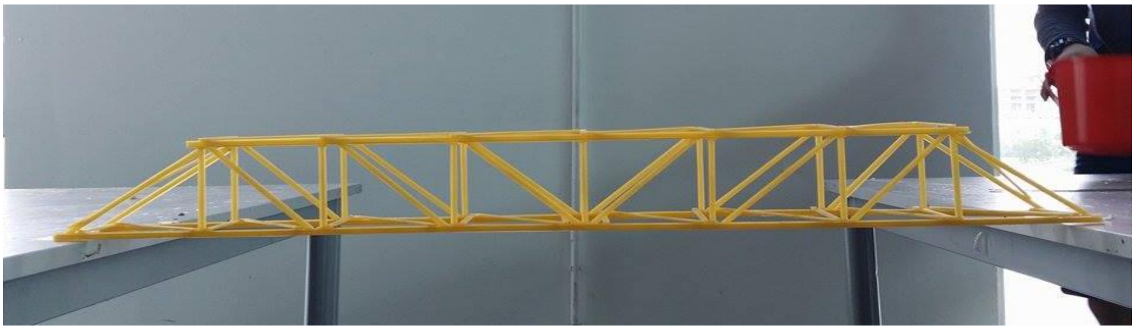
Throughout the bridge testing, Pratt truss were the strongest truss design to be tested for final model making. There are 3 Pratt truss with different shape to be choose and test which one can withstand the highest load.

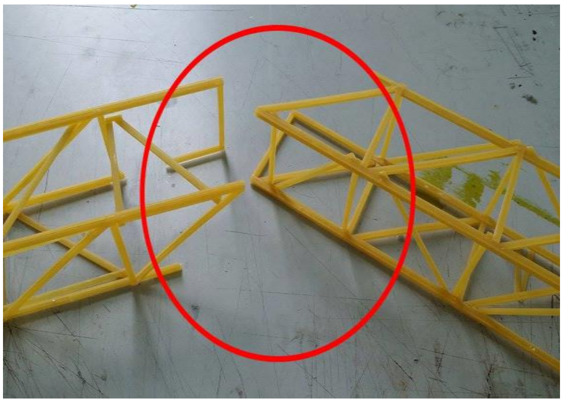
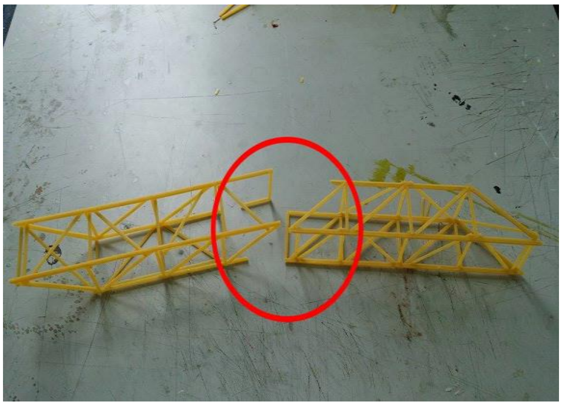
Fettuccini Bridge Design 1



Top view





Total length = 800mm

Clear span = 750mm

Efficiency = 80%

Weight of bridge = 200g

Load sustained = 4kg

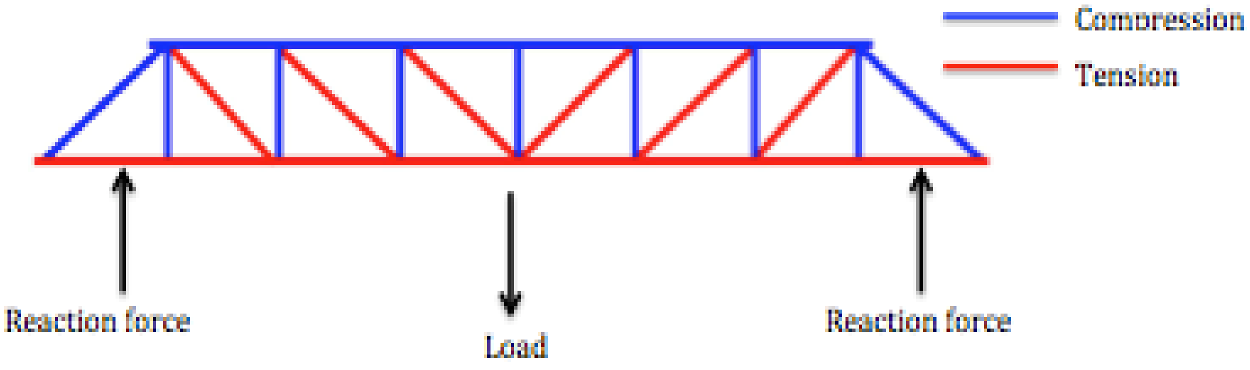
Problem: Failure upon craftsmanship

For this model at first, we assume that the failure will be in structure and it may occur on the middle member which under compression force since fettuccine is poor in compression force. However, it shows that the frame is still intact, just the minor members failed upon craftsmanship.

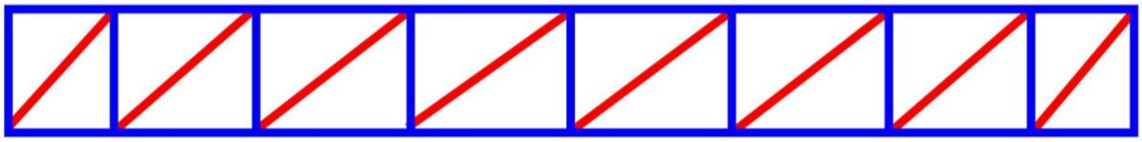
Solution :

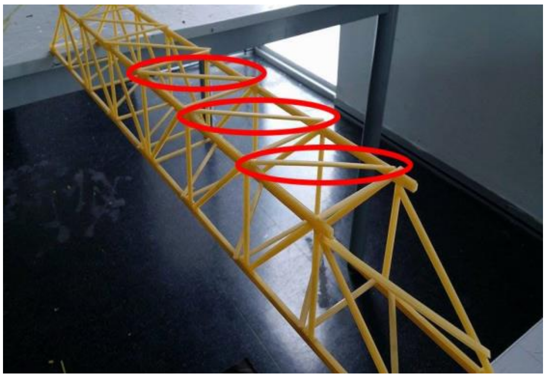
1. Change the shape of the bridge
2. Better craftsmanship to increase efficiency

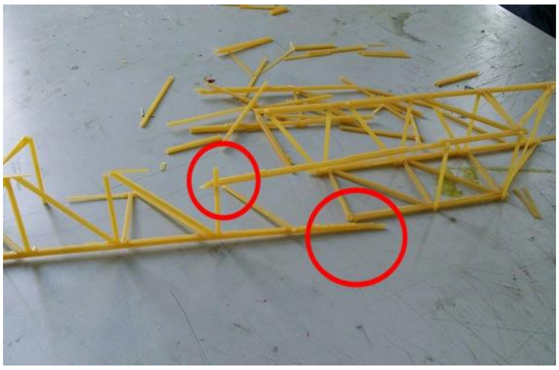
Fettuccini Bridge Design 2



Top view







Total length = 800mm	Weight of bridge = 210g
Clear span = 750mm	Load sustained = 7.5kg
Efficiency = 268%	

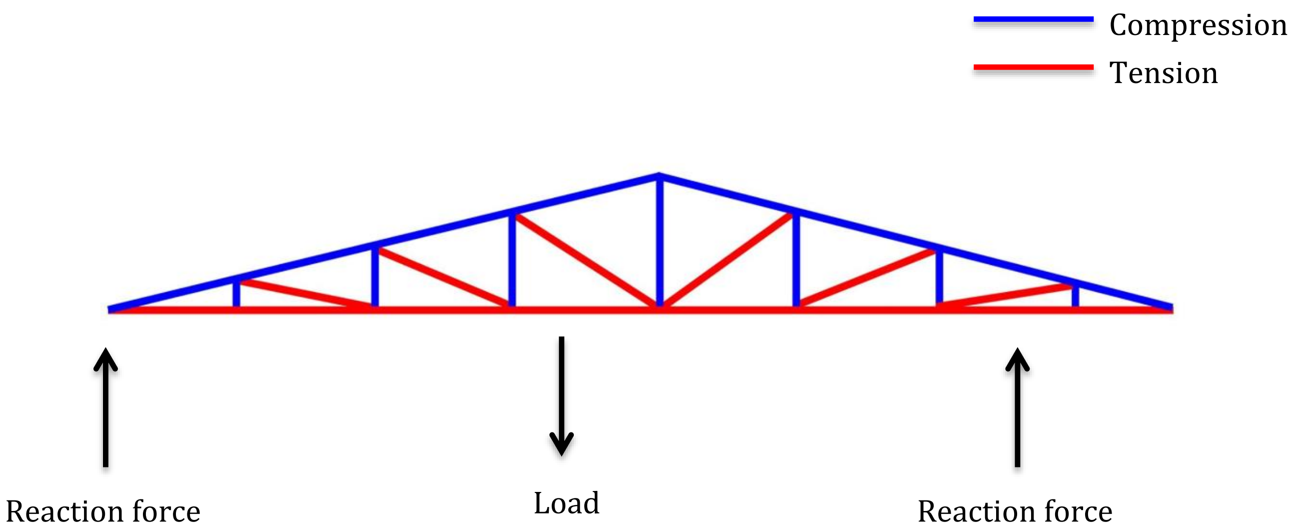
Problem: Bridge is twisting when load applied

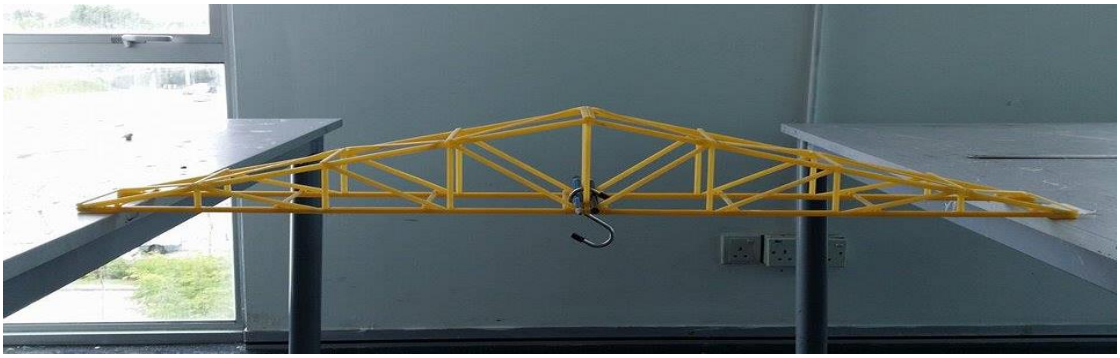
Top bracings are added to make the bridge more stable. The intermediate posts and main ties experience less compressive and tensile force compared to the upper and lower chords. They do not form the main support of the building but merely holds the upper and lower chords in place. If one of the internal members snaps, the bridge may still stand. Few layers of bracing are added and making the bridge heavier.

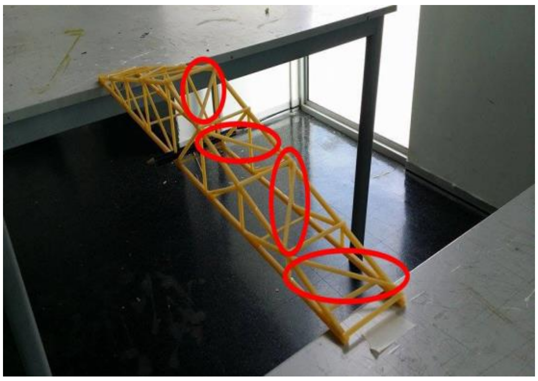
Solution:

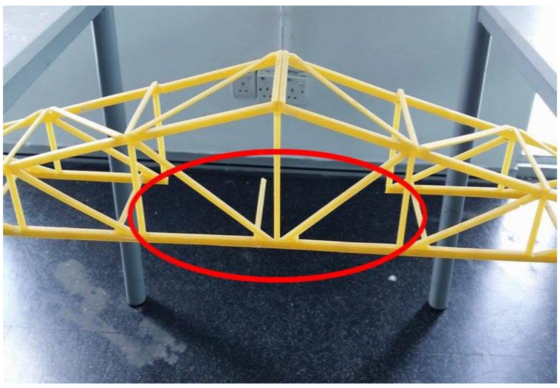
1. Change the shape of the bridge
2. Strengthen the vertical joints
3. Reduce the layer of bracing

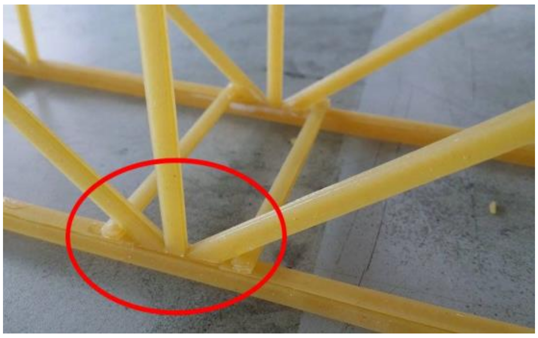
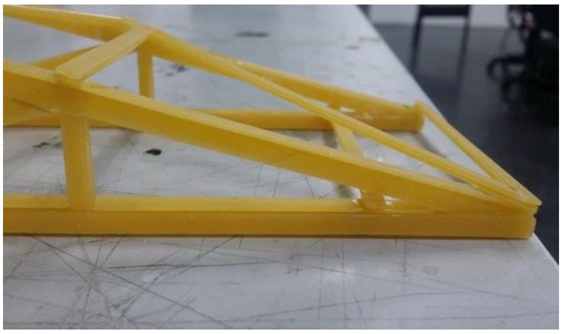
Fettuccini Bridge Design 3 (Final Design)









Total length = 800 mm
Clear span = 750mm
Efficiency = 609%
Problem:

Weight of bridge = 181g
Load sustained = 10.5kg

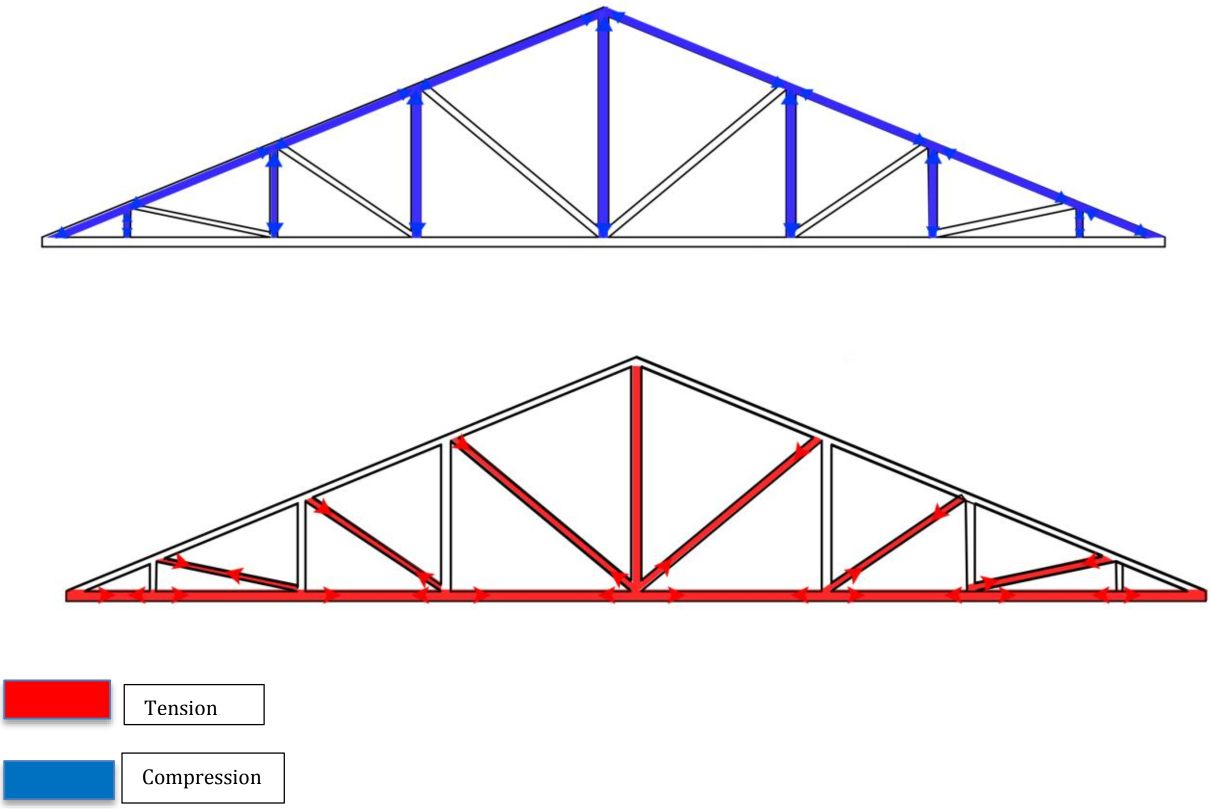
By changing the shape of the bridge, it can withstand more loads thus increase the efficiency. From the truss analysis we made we found out that all the upper structures were under compression and the lower structures were under tension. The inner structures which are the bracings underwent both compression and tension as shown in the diagram. Different ways of constructing the members were used to strengthen the different parts of the structure which underwent different internal forces.

The fettuccine stick has a brittle nature, which makes it relatively weak in compressive strength. In order to prevent the upper chords from snapping, the upper and lower chords were thickened by adding additional fettuccine layers. This allows the upper chords to distribute compressive force without snapping easily.

Summary of Final Fettuccini Bridge

Apparently, the efficiency of final design is boost up to 609%. Good workmanship and good design for load transfer are the main reasons to achieve that level of efficiency for Fettuccine Bridge. In addition, the final model is done just five hours before the final testing to reduce the chemical side effect of superglue. The longer the time after Fettuccine Bridge has being done, the more chemical effect will react on the bridge, and the lower the efficiency will be.

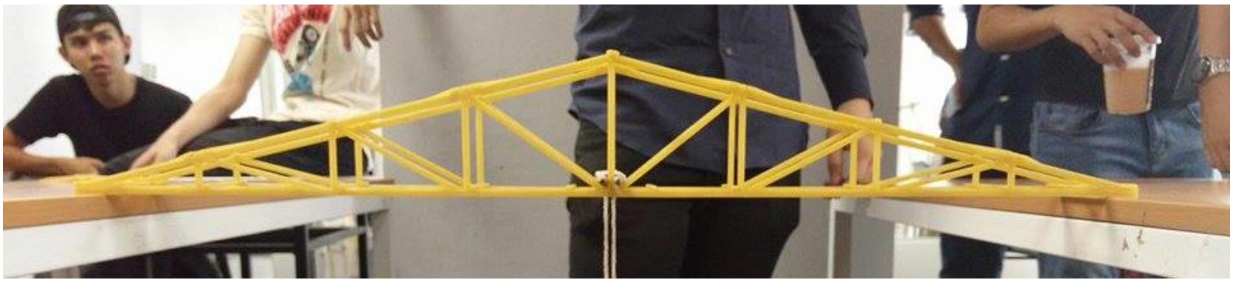
7. Conclusion

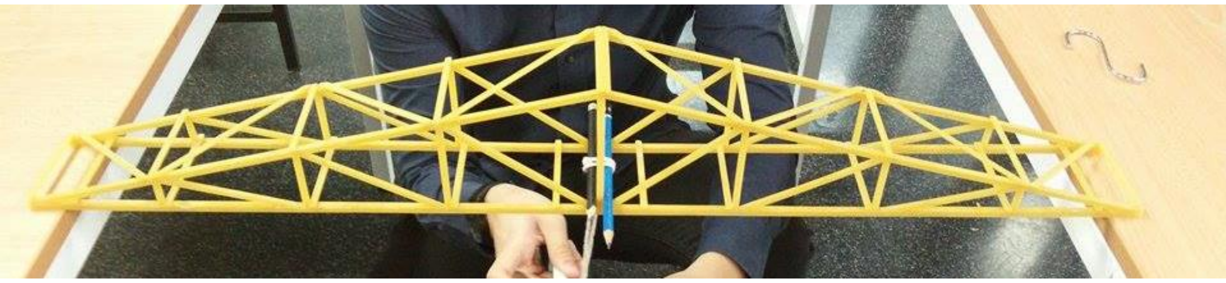


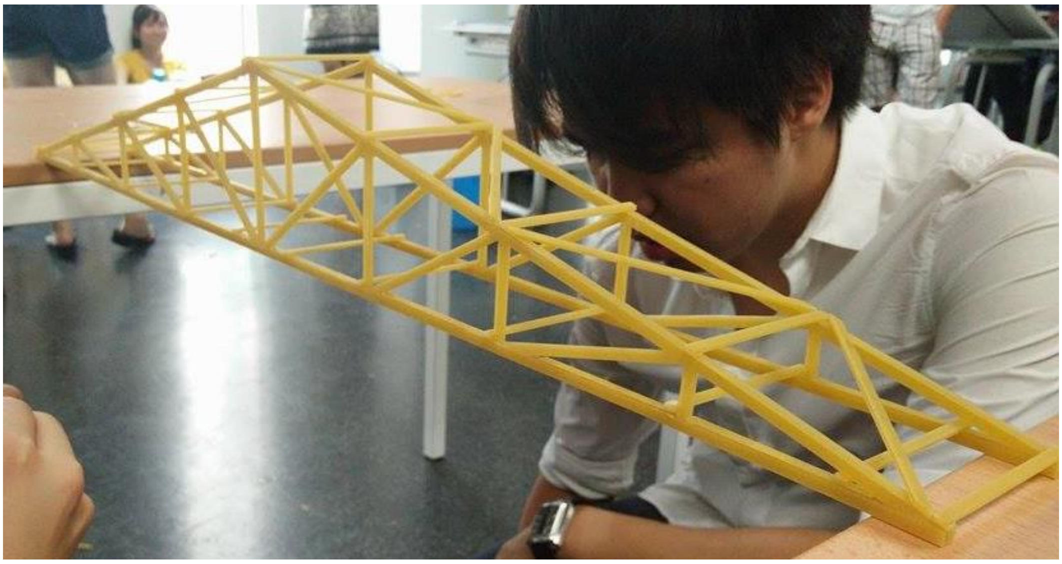
As a result to achieve higher efficiency, truss member need to be modified. Higher tension and compression can be reduce by applying proper jointing and craftsmanship. In terms of upper structure and inner structure, only members under tension forces need to be strengthened.

8. Appendix

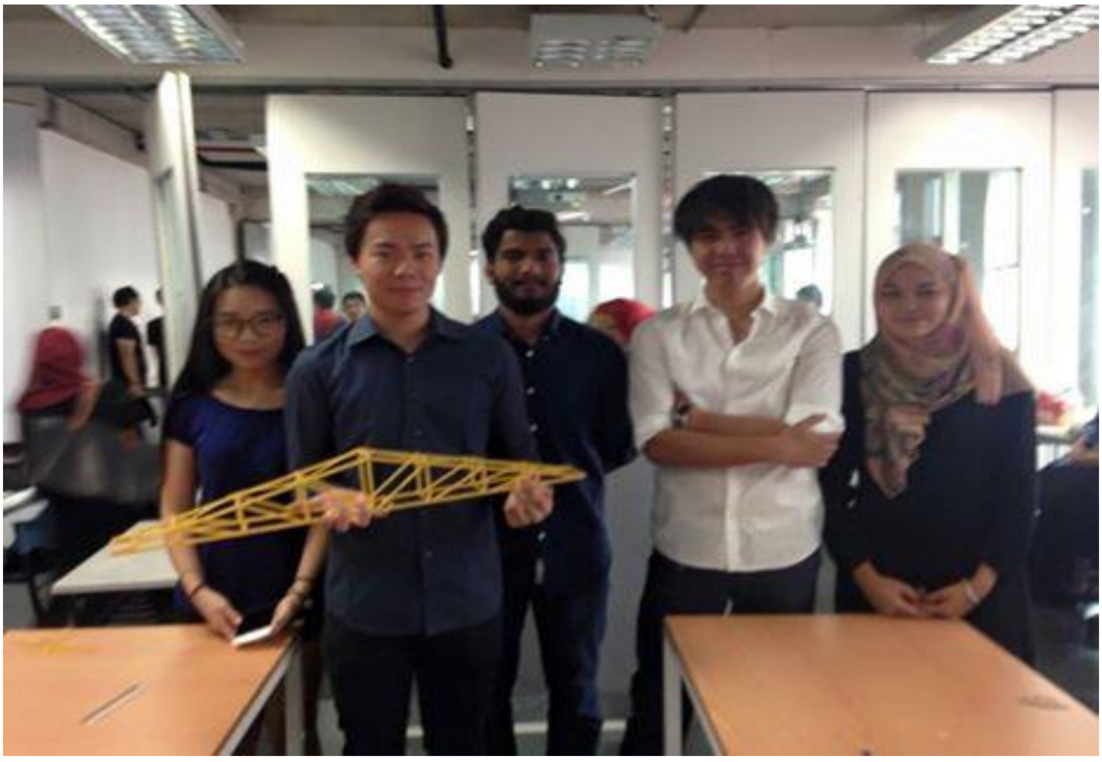
Final Bridge Photos







Group Photos

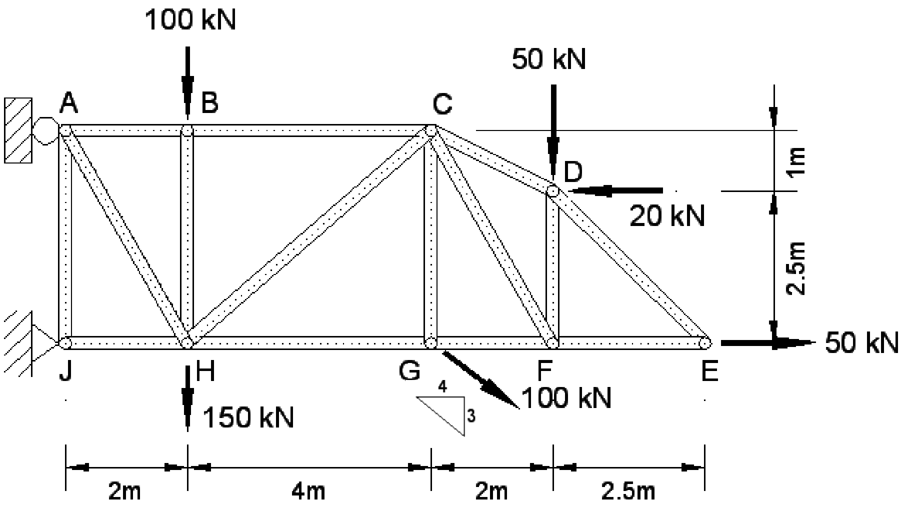


Exercise (Truss Analysis)

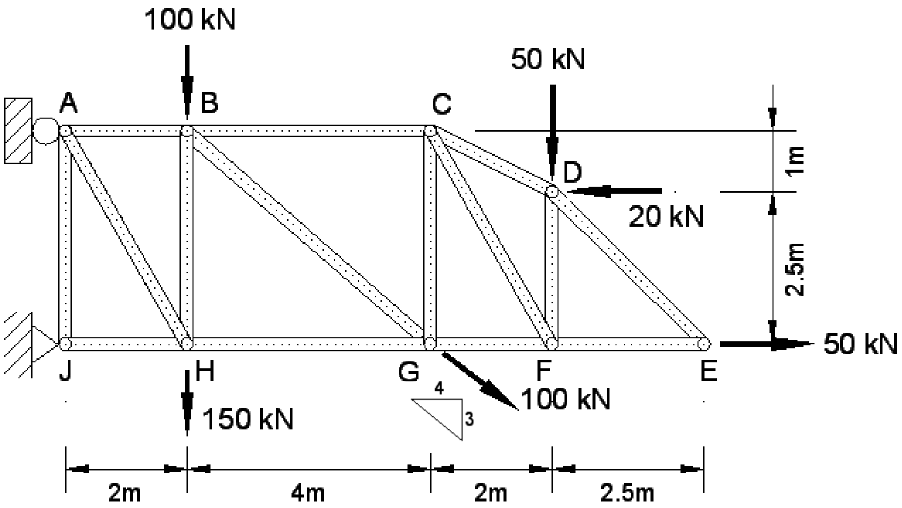
Following are 6 different truss systems which carry exactly the same loads. Each group member analyses one of the following case. Determine which truss arrangement is the most effective and explain why.

(Note: Please write your name on your calculation sheets. Omit case 6 if your group has only 5 members).

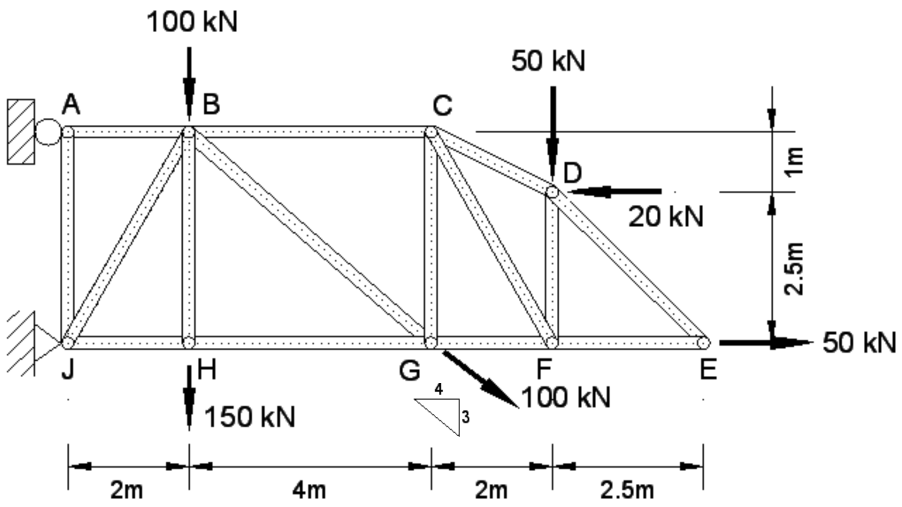
Case 1



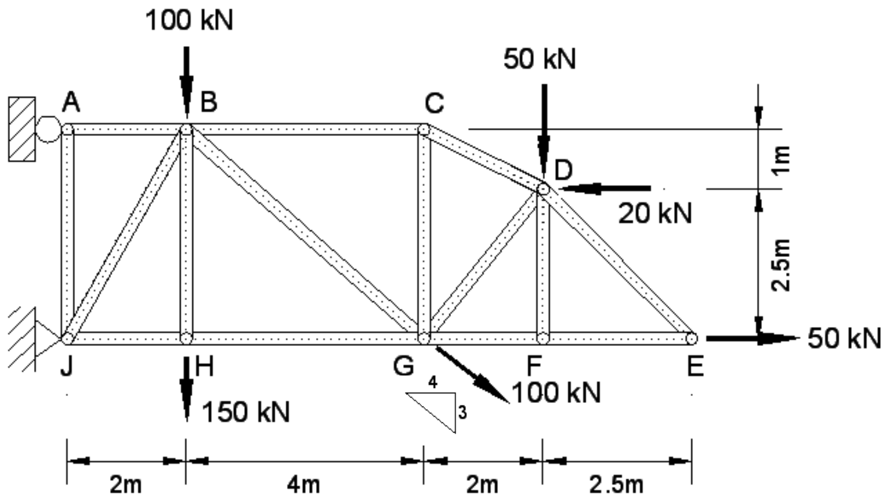
Case 2



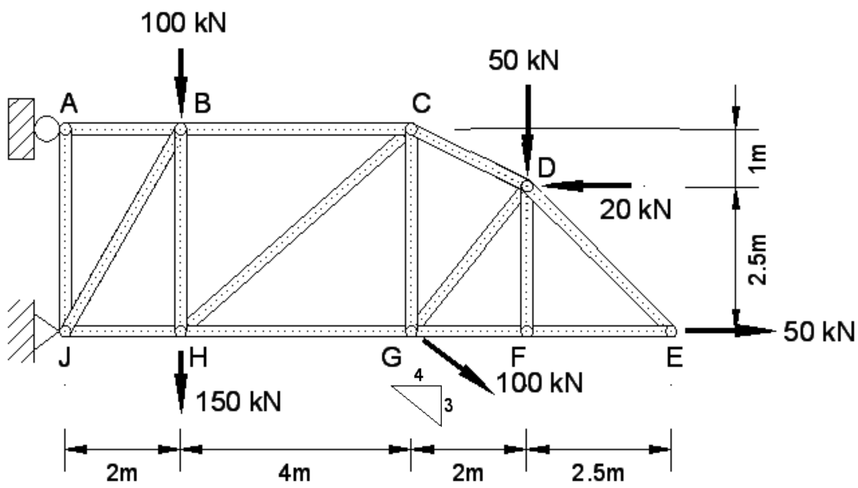
Case 3



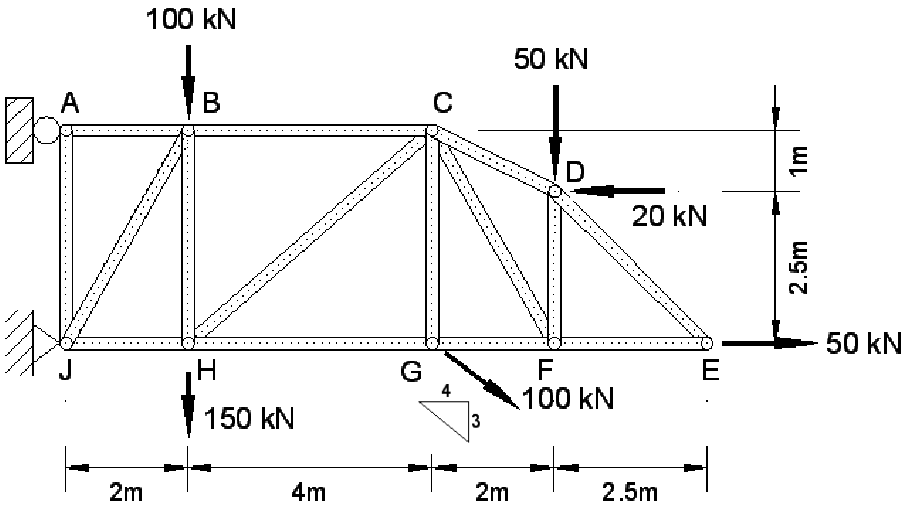
Case 4



Case 5.



Case 6


100 kN
50 kN
A
B
C
D
20 kN
1m
2.5m
50 kN
J
H
G
F
E
100 kN
4
3
150 kN
2m
4m
2m
2.5m

CASE STUDY 1

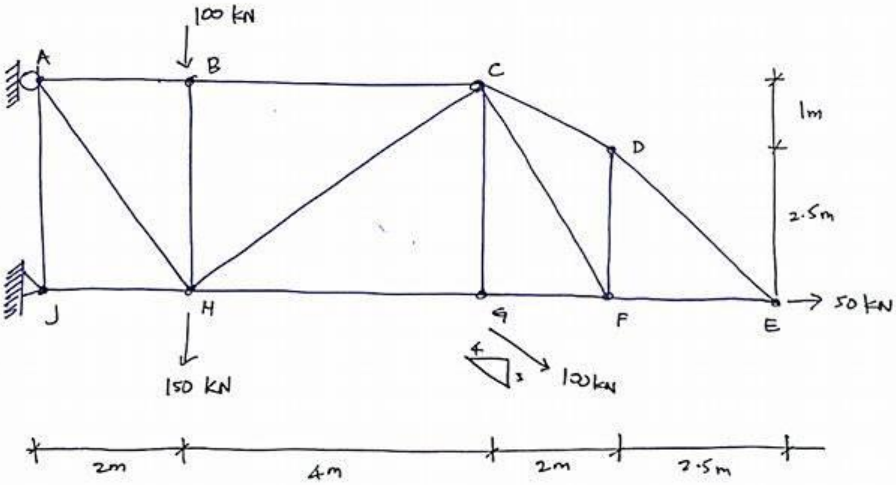
IBRAHIM ADHNAN (0314694)

CASE 1

* Assuming all the members of the bridge is tension.

Therefore positive answer = Tension

Negative answer = Compression.



Determining Perfect Truss

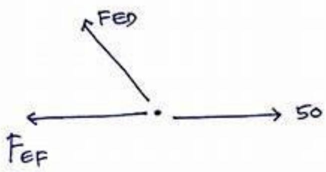
$$2J = m+3$$

$$2(9) = 15+3$$

$$18 = 18 \longrightarrow \text{Perfect Truss.}$$

Determing Internal forces

Joint E



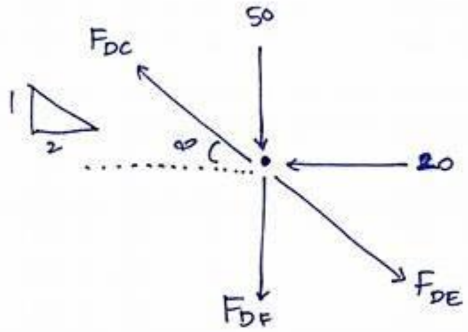
$F_{ED} \cos\theta = 0$

$\therefore$ $F_{ED} = 0$

Horizont Forces

$F_{EF} = +50kN$ tension.

Joint D



$\theta = \tan^{-1}(1/2)$

$\theta = 26.57°$

Horizontal Forces

$20 + F_{DC}\cos\theta = 0$

$F_{DC} = \frac{-20}{\cos 26.57}$

$F_{DC} = -22.35\ kN$ → Compression (−ve)

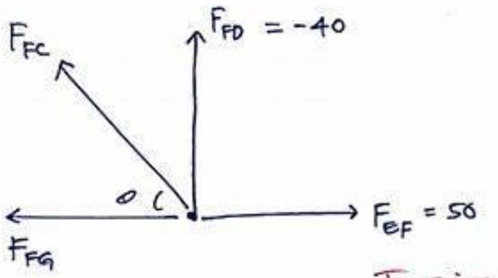
Vertical Forces

$50 + F_{DF} - F_{DC}\sin\theta = 0$

$F_{DF} = 22.35 \sin 26.67 - 50$

$F_{DF} = -40\ kN$ → Compression. (−ve)

Joint F



$\theta = \tan^{-1}\left(\frac{3.5}{2}\right)$

$\theta = 60.26°$

Vertical Forces

$F_{FD} + F_{FC}\sin\theta = 0$

$-40 + F_{FC}\sin 60.26 = 0$

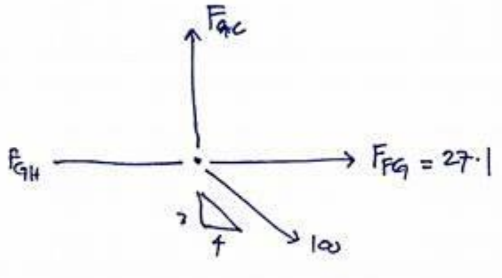
Tension ← (+ve) $F_{FC} = +46.07\ kN$

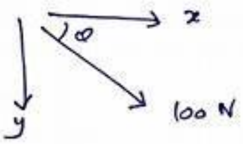
Horizontal Forces

$F_{Fe} = F_{FG} + F_{FC}\cos\theta$

Tension. ← (+ve) $F_{Fg} = +27.1\ kN$

Joint G





$\theta = \tan^{-1}(3/4)$

$= 36.87°$

$x = 100\cos 36.87 = 80\ kN$

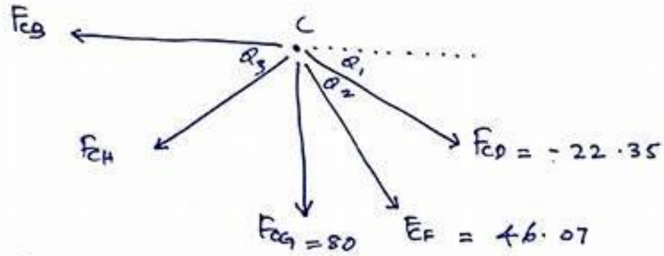
$y = 100\sin 36.87 = 60\ kN$

→

(3)

Vertical Forces	Horizontal Forces
$F_{GC} = 100 \cos 36.87$	$F_{GH} = F_{GF} + 100 \sin \theta$
$F_{GC} = 80 \text{ KN}$ → +ve → tension	$F_{GH} = 27.1 + 60$
	$F_{GH} = +87.1 \text{ KN}$ → +ve → tension

Joint C



$\theta_1 = \tan^{-1}(1/2) = 26.65°$

$\theta_2 = 60.25°$

$\theta_3 = 41.19°$

Vertical Forces

$F_{CD} \sin\theta_1 + F_{CF} \sin\theta_2 + F_{CG} + F_{CH} \sin\theta_3 = 0$

$-22.35 \sin 26.65 + 46.07 \sin 60.25 + 80 + F_{CH} \sin 41.19 = 0$

$F_{CH} = \frac{-110}{\sin 41.19}$

$F_{CH} = -167 \text{ KN}$ → -ve → Compression.

Horizontal Forces

$F_{CB} + F_{CH} \cos\theta_3 = F_{CF} \cos\theta_2 + F_{CD} \cos\theta_1$

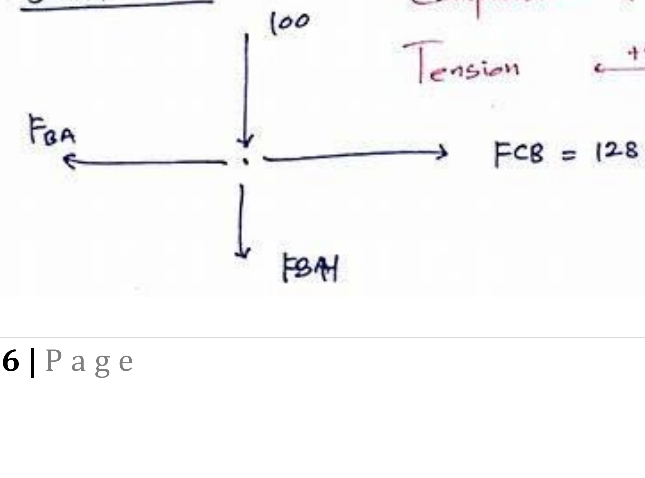
$F_{CB} = 46.07 \cos 60.25 - 22.35 \cos 26.65 + 167 \cos 41.19$

$F_{CB} = +128 \text{ KN}$ → Tension

Joint B

Compression ← -ve ← $F_{BH} = -100 \text{ KN}$ - Vertical

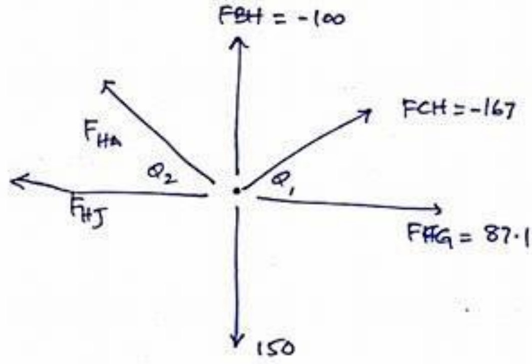
Tension ← +ve ← $F_{BA} = +128 \text{ KN}$ → Horizontal



(4)

Joint H

~~Vertical Forces~~
~~150 = 100 + (-167 sin~~



$$\theta_1 = \tan^{-1}(3.5/4) = 41.19^\circ$$
$$\theta_2 = \tan^{-1}(3.5/2) = 60.26^\circ$$

Vertical Forces

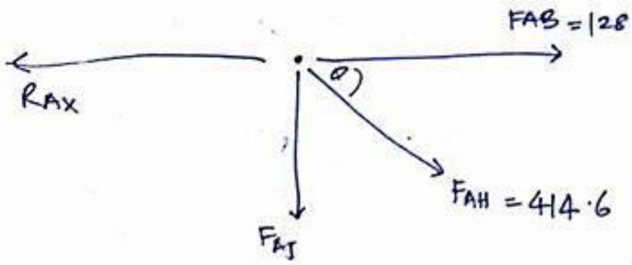
$$150 = -100 + (-167 \sin \overset{\theta_1}{41.19}) + F_{HA} \sin \overset{\theta_2}{60.26}$$
$$150 = -100 - 110 + F_{HA} \sin 60.26$$
$$\boxed{F_{HA} = 414.6 \text{ kN}}$$ → Tension (+ve)

Horizontal Forces

$$F_{HJ} + F_{HA} \cos\theta = F_{HC} \cos\theta + F_{HG}$$
$$F_{HJ} + 414.6 \cos 60.26 = -167 \cos 41.19 + 87.1$$
$$\boxed{F_{HJ} = -224.24}$$ → compression (-ve)

Joint A

$$\theta = \tan^{-1}(3.5/2) = 60.26^\circ$$



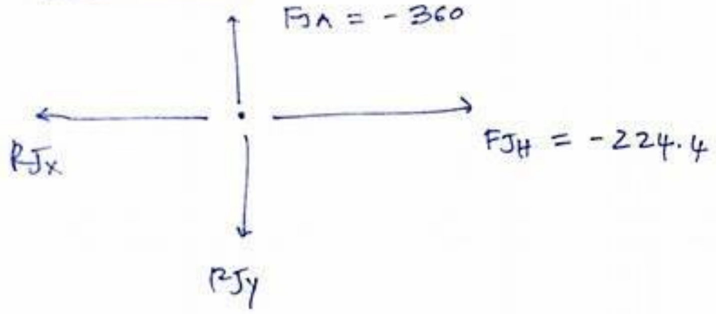
Horizontal Forces

$$F_{AX} = 128 + 414.6 \cos 60.26$$
$$\boxed{F_{AX} = 333.67 \text{ kN}}$$ → tension (+ve)

Vertical Forces

$$F_{AJ} = -F_{AH} \sin\theta$$
$$= -414.6 \sin 60.26$$
$$\boxed{F_{AJ} = -360 \text{ kN}}$$ → Compression (-ve)

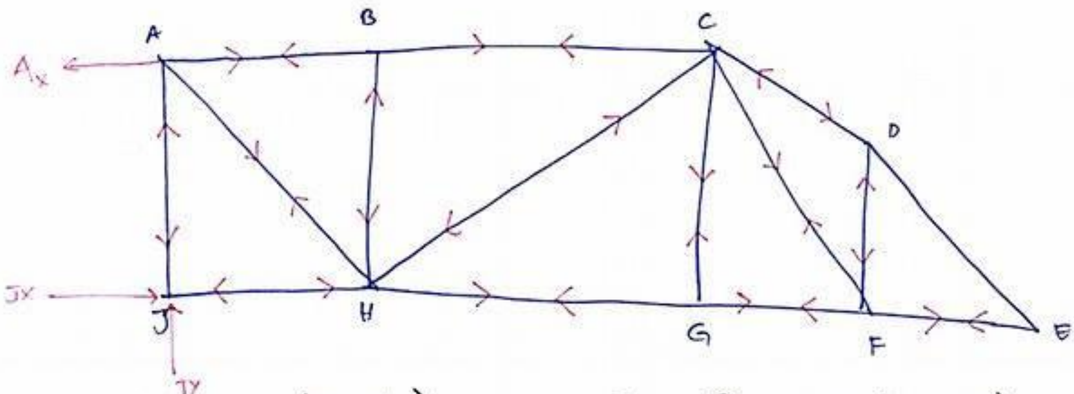
Joint J



∴ RJY = - 360 kN → -ve → Compression

RJx = - 224.4 kN → -ve → Compression.

Forces Determined



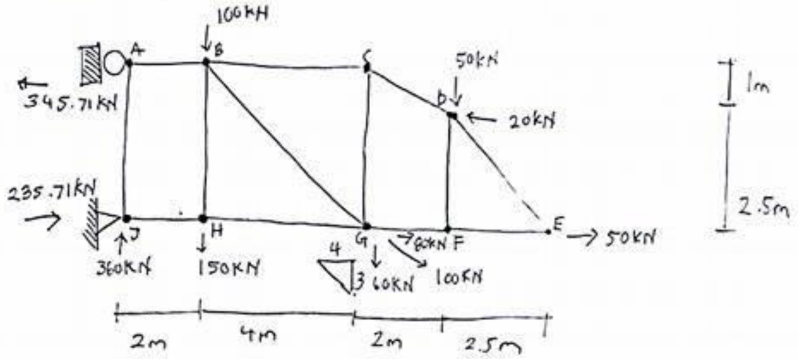
JY = Compression (360 kN)
FE = Tension (50 kN)
DC = Compression (22.35 kN)
DF = Compression (40 kN)
FC = Tension (46.07 kN)
FG = Tension (27.1 kN)
HA = Tension (414.6 kN)
HJ = Compression (224.24)

RJx = Compression (224.4)
GC = Tension (80 kN)
GH = Tension (87.1 kN)
CH = Compression (467 kN)
CB = Tension (128 kN)
BH = Compression (100 kN)
BA = Tension (128 kN)
AX = Tension (333.67 kN)
AJ = Compression (360 N)

CASE STUDY 2

IMRAN SUHAIMI (0311624)

IMRAN SUHAIMI B. MUHAMMAD ALI
0311624



Number of Joints : 2J = m + r
2(9) = 15 + 3
18 = 18
∴ It's a perfect truss

At point G
By ratio, FG_x = 80kN
FG_y = 60kN

$\Sigma F_x = 0$, $\Sigma F_y = 0$, $\Sigma m = 0$

$\Sigma F_y = 0$
$FJ_y - 100 - 50 - 150 - 60 = 0$
FJ_y = 360kN

At point J, $\Sigma m = 0$
$(100 \times 2) + (50 \times 8) + (150 \times 2) + (60 \times 6) + (-20 \times 2.5) + (F_{Ax} \times 3.5) = 0$

$3.5 F_{Ax} = -1210$
$F_{Ax} = -345.71$ kN
Assumed direction of forces wrong...

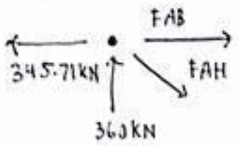
$\Sigma F_x = 0$
$FJ_x - 345.71 - 20 + 80 + 50 = 0$
FJ_x = 235.71kN

Determine Internal Forces

At point J
$\Sigma F_x = 0$
$235.71 - F_{HJ} = 0$
F_{HJ} = 235.71kN
(Compression)

$\Sigma F_y = 0$
$360 - F_{AJ} = 0$
F_{AJ} = 360kN (compression)

At point A,



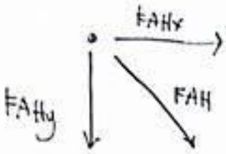
$\Sigma F_y = 0$

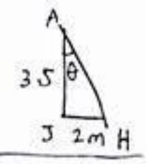
$360 - F_{AHy} = 0$

$360 - F_{AH} \cos 29.74 = 0$

$F_{AH} = 414.61 \text{ kN}$

(Tension)





$\tan\theta = \frac{2}{3.5}$

$\theta = 29.74$

$\sin 29.74 = \frac{F_{AHx}}{F_{AH}}$

$F_{AHx} = F_{AH} \sin 29.74$

$\cos 29.74 = \frac{F_{AHy}}{F_{AH}}$

$F_{AHy} = F_{AH} \cos 29.74$

$\Sigma F_x = 0$

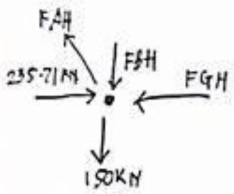
$F_{AB} - 345.71 + F_{AHx} = 0$

$F_{AB} - 345.71 + F_{AH} \sin 29.74 = 0$

$F_{AB} = 140.04 \text{ kN}$

(Tension)

At point H,



$\Sigma F_x = 0$

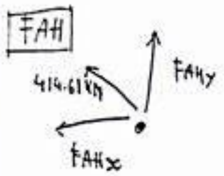
$235.71 - F_{GH} - F_{AHx} = 0$

$235.71 - F_{GH} - 414.61 \sin 29.74 = 0$

$F_{GH} = 30.04 \text{ kN}$

(compression)

FAH



$\Sigma F_y = 0$

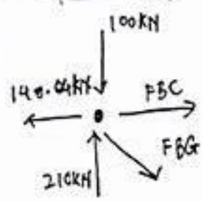
$F_{AHy} - F_{BH} - 150 = 0$

$414.61 \cos 29.74° - F_{BH} - 150 = 0$

$F_{BH} = 210 \text{ kN}$

(compression)

At point B.



$\Sigma F_y = 0$

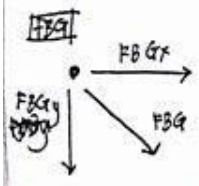
$210 - 100 - F_{BGy} = 0$

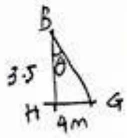
$110 = F_{BG} \cos 48.81$

$F_{BG} = 167.03 \text{ kN}$

(Tension)

FBG





$\tan\theta = \frac{4}{3.5}$

$\theta = 48.81$

$\sin 48.81 = \frac{F_{BGx}}{F_{BG}}$

$F_{BGx} = F_{BG} \sin 48.81$

$\cos 48.81 = \frac{F_{BGy}}{F_{BG}}$

$F_{BGy} = F_{BG} \cos 48.81$

$\Sigma F_x = 0$

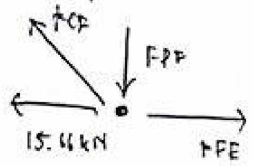
$F_{BC} - 140.04 + F_{BGx} = 0$

$F_{BC} - 140.04 + F_{BG} \sin 48.81 = 0$

$F_{BC} = 14.34 \text{ kN}$

(Tension)

At point F



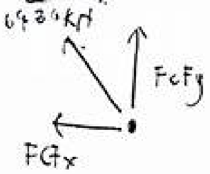
$\Sigma F_x = 0$

$FFE - 15.66 - FCF_x = 0$

$FFE - 15.66 - 69.30 \cos 60.26° = 0$

$FFE = \underline{50.04 kN}$ (tension)

FCF



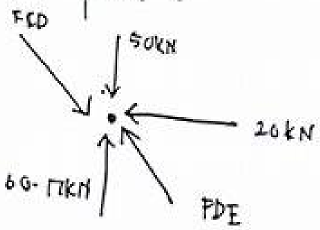
$\Sigma F_y = 0$

$FCF_y - FDF = 0$

$69.30 \sin 60.26 - FDF = 0$

$FDF = \underline{60.17 kN}$ (compression)

At point D



$\Sigma F_x = 0$

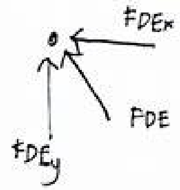
$FCD_x - 20 - FDE_x = 0$

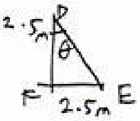
~~FCDx = 2~~

$22.87 \cos 26.57 - 20 - FDE \sin 45 = 0$

$FDE = 0.64 kN$ (compression)

FDE

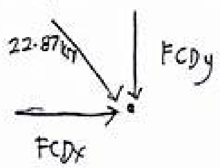




$\tan \theta = 1$

$\theta = 45°$

FCD



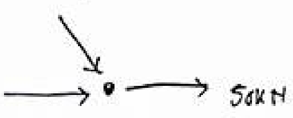
$\Sigma F_y = 0$

$60.17 - 50 - FCD_y + FDE_y = 0$

$60.17 - 50 - 22.87 \sin 26.57 + FDE \cos 45 = 0$

$FDE = 0.08 kN$ (compression)

At point E



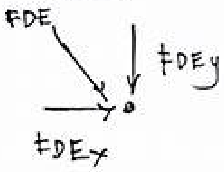
$\Sigma F_x = 0$

$50 - 50.04 + FDE_x = 0$

$FDE \sin 45° - 0.04 = 0$

$FDE = 0.06 kN$ (compression)

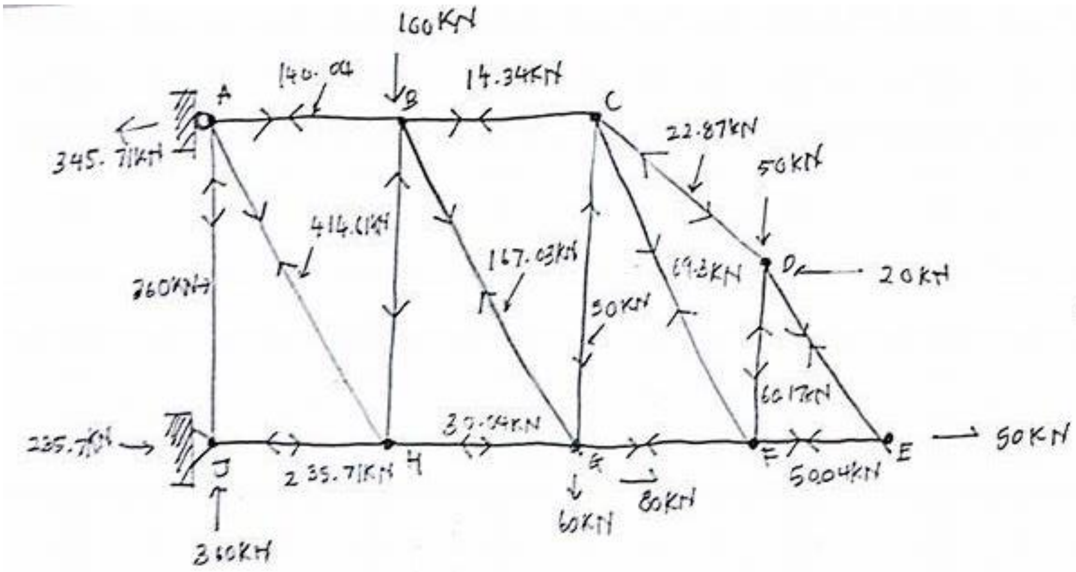
FDE



$\Sigma F_y = 0$

$\Sigma DE_y = 0$

$FDF = 0 kN$ (compression)



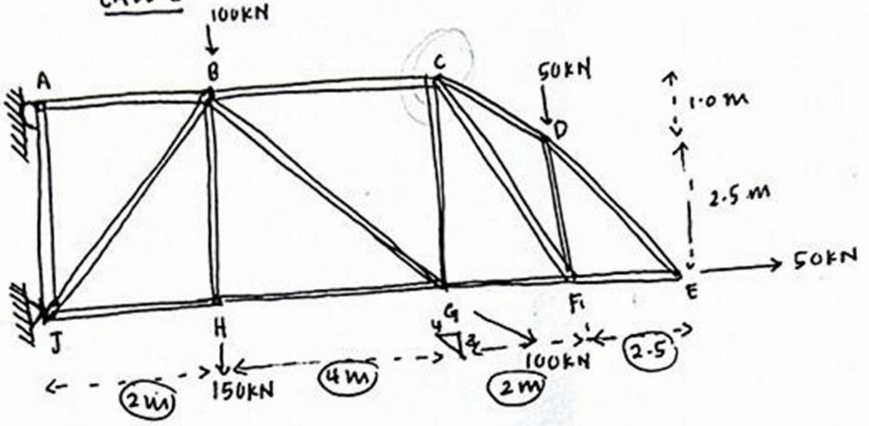
AJ highest compression members.

CASE STUDY 3

NADZIRAH HANIS (0311096)

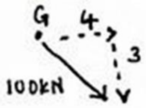
[NADZIRAH HANIS (0311096)]

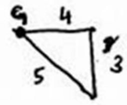
CASE 3



∴ Joint A is a roller joint

$R_{Ay} = 0$



① 

$\tan x = \frac{3}{4}$

$x = 36.87°$

$\cos 36.87° = \frac{f_{Gx}}{f_G}$

$\cos 36.87° = \frac{f_{Gx}}{100}$

$\boxed{f_{Gx}} = 80kN$ *

② $\sin 36.87° = \frac{f_{Gy}}{f_G}$

$\sin 36.87° = \frac{f_{Gy}}{100}$

$\boxed{f_{Gy}} = 60kN$ *

NADZIRAH HANIS (0311096)

$\therefore \Sigma fy = 0$

$-100\,kN - 50\,kN - 60\,kN - RJy = 0$

$-100\,kN - 50\,kN - 150\,kN - 60\,kN = RJy$

$-360 = RJy$ ∴ The assumed direction of $R\delta y$ is incorrect.

$\therefore \Sigma M = 0$

$Rax(3.5) + 100(2) + 50(8) - 20(2.5) + 50(0) + 150(2)$

$60(6) = 0$

$3.5\,Rax + 200 + 400 - 50 + 300 + 360 = 0$

$1210 = -3.5\,Rax$

$\frac{1210}{-3.5} = Rax$

$RAx = -345.71\,kN$ ##

$\Sigma fx = 0$

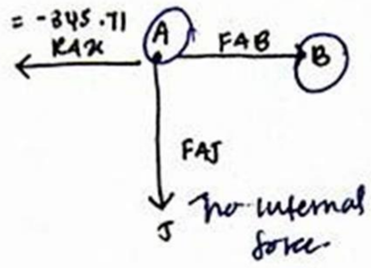
$-R4x - 20 + 50 + 80 + RJx = 0$

$-345.71 + 110 + RJx = 0$

$RJx = 235.71\,kN$ ##

NADZIRAH HANIS (0311096)

JOINT A.



$\therefore \Sigma fx = 0$

$-345.71 + fAB = 0$

$FAB = 345.71\ kN$

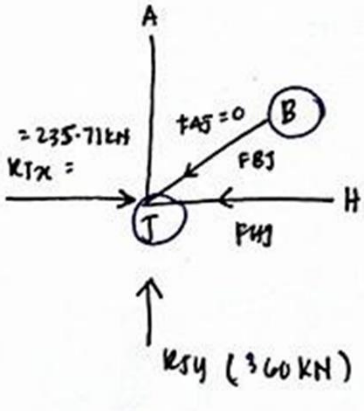
$\therefore$ AB is in "tension"

$\therefore \Sigma fy = 0$

$FAJ = 0$

$\therefore$ There's no internal force in AJ.

JOINT J

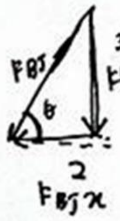


$\therefore \Sigma fy = 0$

$360 - f_{BJ} \sin 60.26° = 0$

$\therefore FBJ = 414.61\ kN$

(member of BJ is in compression)



$\tan \theta = \frac{3.5}{2}$

$\theta = 60.26°$

~~FABJ~~ $FBJx = FBJ \cos 60.26°$

$FBJy = FBJ \sin 60.26°$

$\therefore \Sigma f x = 0$

$235.71 - FHJ - (414.61) \cos 60.26° = 0$

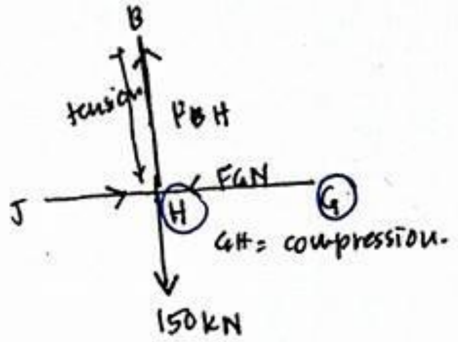
$FHJ = 30.04\ kN$

$\therefore$ member HJ is in compression.

NADZIRAH HANIS (0311096)

Pg 11

JOINT H



$\Sigma f_x = 0$

$\therefore +30.04 - F_{GH} = 0$

$F_{GH} = 30.04\ KN$

$\therefore$ member GH is in compression.

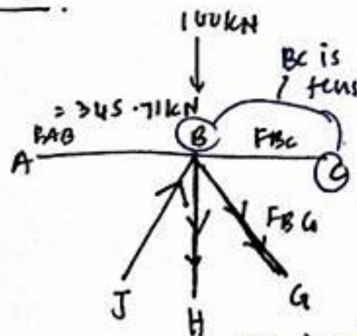
$\Sigma f_y = 0$

$\therefore F_{BH} - 150 = 0$

$F_{BH} = 150\ KN$

$\therefore$ BH is in tension

JOINT B



$F_{BJ} = 414.61\ KN$

$F_{BH} = 150\ KN$

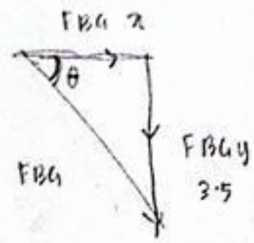
$\Sigma F_y = 0$

~~414.18~~

BG = tension. $414.61 \sin 60.26° - 150 - F_{BG} \sin 41.18° - 100 = 0$

$\therefore F_{BG} = 167.05\ KN$

$\therefore$ member BG is in tension.



$\tan x = \frac{3.5}{4}$

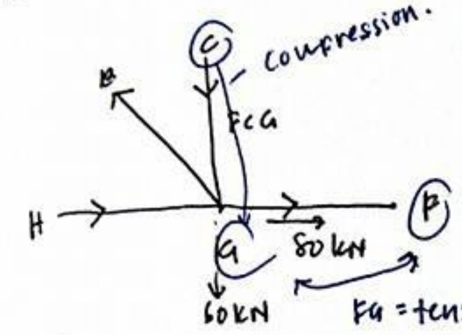
$x = 41.18°$

$\Sigma f_x = 0$

$= -345.71 + 414.61 \cos 60.26 + 167.05 \cos 41.18 + F_{BC} = 0$

$F_{BC} = 14.307\ KN$

JOINT G.



~~Σfx=0~~

Σfx=0

F~~FG~~ + 30.04 + 80 - 167.63 cos 41.19°

∴ FFG = 15.632 kN #

FG member is a tension.

FGH = 30.04 kN

~~Σfy=0~~

~~- FCG ... 30.04 ... 80 ... 41.18°~~

Σfy = 0

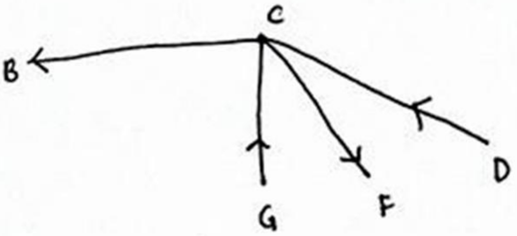
- FCG + 167.05 sin 41.18° - 60 = 0

= FCG = 50 kN #

= "~~BH~~" members is in ~~tension~~ compression.

NADZIRAH HANIS (0311096)

JOINT C .



tan ⁻ = $\frac{1}{2}$

= ~~...~~°.

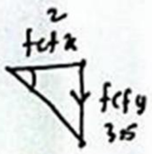
= 26.57°

fdx : fcd cos 26.57

= 0.894 fcd

Fcdy = Fcd 26.57

y = 0.447 Fcd



tan θ = $\frac{3.5}{2}$

= 60.26°

~~Ffy~~ Ffx = Fcf cos 60.26°

x = 0.496/05 fcf.

ffy : fcf sin 60.26

= 0.868

Σfy = 0.447 Fcd + 50 − 0.868 Fcf = 0

0.447 Fcd − 0.868 Fcf = −50 —— ①.

Σfx = 0

14.307 − 0.894 Fcd + 0.496 fcf = 0

−0.894 Fcd + 0.496 fcf = −14.307 —— ②

: 0.894 × ② − 0.447 (①)

: 0.894 (0.868 Fcf) − 0.447 (0.496) = 0.447 (−14.307) − 0.894 (−0.496)

0.5543 fcf = 38.29

Fcf = 69.078 kN

"member CF = tension"

NADZIRAH HANIS (0311096)

$$0.894F_{cd} - 0.496(69.078) = -14.307$$

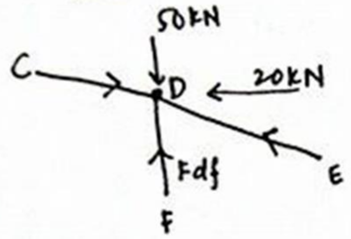
$$0.894F_{cd} = 19.955$$

$$\therefore F_{CD} = 22.32 \text{ kN}$$

"member CD = compression"

NADZIRAH HANIS (U311096)

JOINT D.

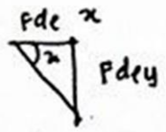


Fcdx = 0.894 (22.32)

= 19.95 KN

Fcdy = 0.447 (22.32)

= 9.977 KN



$\tan x = \frac{2.5}{2.5}$

= 45

$\Sigma fx = 0$

∴ 19.95 - fde cos45 - 20 = 0

- fde cos45 = 0.05

fde = - 0.0707

≈ 0

There is no internal force in member DE.

$\Sigma fy = 0$

- 9.977 + (0) ~~sin 45~~ - 50 + FDF = 0

- 59.977 + FDF = 0

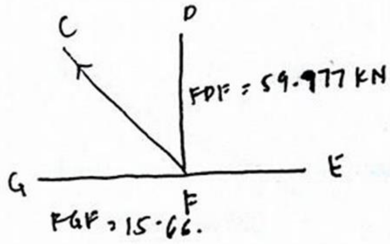
FDF = 59.977 KN

#

member DF = compression

NADZIRAH HANIS (0311096)

JOINT F



Fcy = 0.868 (69.078)
= 59.95 KN

Fcx = 0.496 (69.078)
= 34.26 KN

Σfx = 0

- FEF - 15.66 - 34.26

FEF = - 49.92 KN

"Member EF is a tension."

Σfy = Fcfy - fdf

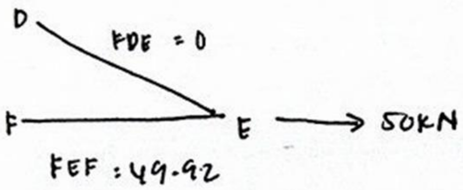
= 59.96 - 59.96

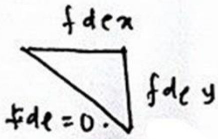
= 0

"Σfy is correct."

NADZIRAH HANIS (0311096)

JOINT E





FDE = 0

$\Sigma fx = -FEF + 50$

$= -49.92 + 50$

$= 0.08$

≈ 0

$\therefore \Sigma fx = 0$

"FEF is correct!"

FDE = 0

FDEy = 0

$\Sigma fy = FDEy$

$\therefore = 0$

"FDE is correct!"

CASE STUDY 4

SEE CUL WEI (0310747)

Phase 1 Determine Perfect Truss

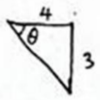
$2J = m + J$

$2(9) = 15 + 3$

$18 = 18$ // ∴ It's a perfect truss.

Phase 2 Determine Reaction Forces

Resolve 100kN at point G



$\tan\theta = \frac{2}{4}$

$\theta = 36°52'$

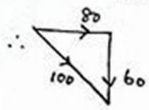
$\sin 36°52' = \frac{y}{100}$

$y = 60kN$

$\cos 36°52' = \frac{x}{100}$

$x = 80kN$

∴



$\Sigma Fy = 0$

$-100 - 50 - 150 - 60 + RJy = 0$

$RJy = 360kN$ //

Moment at point J

$0 = (100 \times 2) + (50 \times 8) + (150 \times 2) + (60 \times 6) + (3.5\ RAx) + (-20 \times 2.5)$

$= 1210 + 3.5\ RAx$

$3.5\ RAx = -1210$

$RAx = -345.714kN\ (\leftarrow)$ //

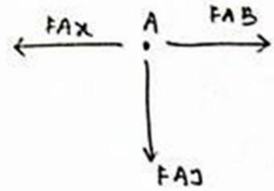
$\Sigma Fx = 0$

$0 = -345.714 - 20 + RJx + 80 + 50 - 235.714 + RJx$

$RJx = 235.714$ //

Phase 3 Determine Internal Forces

1.



$\Sigma Fx = 0$

$-345.71 + FAB = 0$

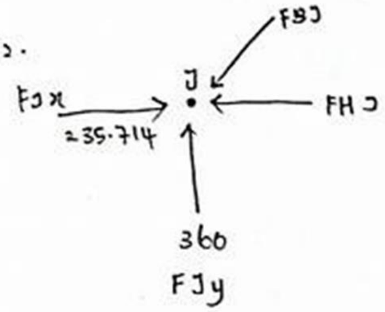
$FAB = 345.71$ //

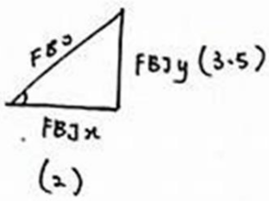
$\Sigma Fy = 0$

$-FAJ = 0$

$FAJ = 0$ //

2.





$\tan\theta = \frac{3.5}{2}$

$\theta = 60.26°$

$\cos 60.26° = \frac{FBJx}{FBJ}$

① $FBJx = FBJ \cos 60.26°$

$\sin 60.26° = \frac{FBJy}{FBJ}$

② $FBJy = FBJ \sin 60.26°$

$\Sigma Fy = 0$

$0 = -FBJy + 360$

$0 = -FBJ \sin 60°26' + 360$

$FBJ \sin 60°26' = 360$

$FBJ = 413.8$ //

$\Sigma Fx = 0$

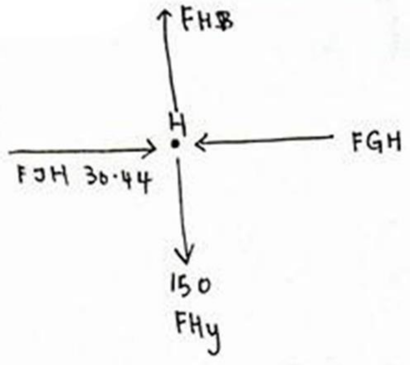
$235.71 - FHJ - FBJx = 0$

$FHJ = -413.8 \cos 60°26' + 235.71$

$= -205.27 + 235.71$

$FHJ = 30.44 kN$ //

3.



$\Sigma F_x = 0$

$0 = 30.44 \quad FGH$

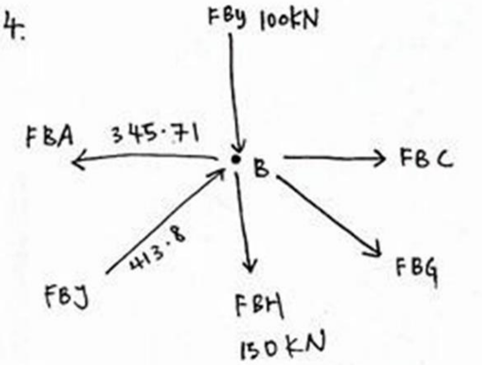
$FGH = 30.44$ //

$\Sigma F_y = 0$

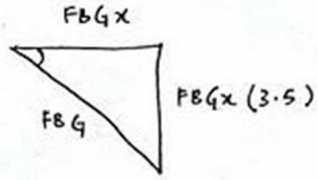
$0 = FHB - 150$

$FHB = 150\ kN$ //

4.



(4)



$\tan\theta = \frac{3.5}{4}$

$\theta = 41.19°$

$\sin 41.19° = \frac{FBGy}{FBG}$

① ——— $FBGy = FBG \sin 41.19°$

② ——— $FBGx = FBG \cos 41.19°$

$\Sigma f_x = 0$

$0 = -345.71 + FBC + FBGx + 205.27$

$0 = FBC + FBGx - 140.44$

$0 = FBC + FBG \cos 41.19° - 140.44$

$0 = FBC + FBG\ 0.753 - 140.44$

$FBC = -FBG\ 0.753 + 140.44$ ——— ③ $FBC = -165.97(0.753) + 140.44$

$FBC = 15.465\ kN$ //

$\Sigma f_y = 0$

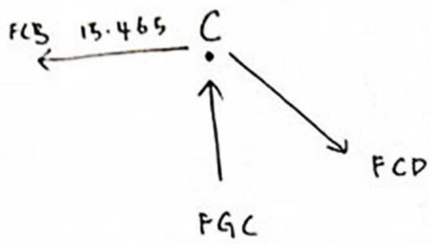
$0 = -100 - FBGy - 150 + 359.30$

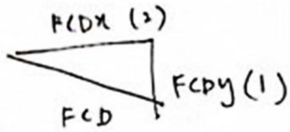
$0 = 109.3 - FBGy$

$0 = 109.3 - FBG \sin 41.19°$

$FBG = 165.97\ kN$ //

5.





$\tan\theta = \frac{1}{2}$

$\theta = 26.57°$

$\sin 26.57° = \frac{FCDy}{FCD}$

① ——— $FCDy = FCD \sin 26.57°$

$\cos 26.57° = \frac{FCDx}{FCD}$

② ——— $FCDx = FCD \cos 26.57°$

$\Sigma Fy = 0$

$0 = -FCDy + FCG$

$FCDy = FCG$

$FCD \sin 26.57° = FCG$

$FCD\ 0.447 = FCG$ ——— ③

$17.291\ (0.447) = FCG$

$FCG = 7.73\ kN$

$\Sigma FX = 0$

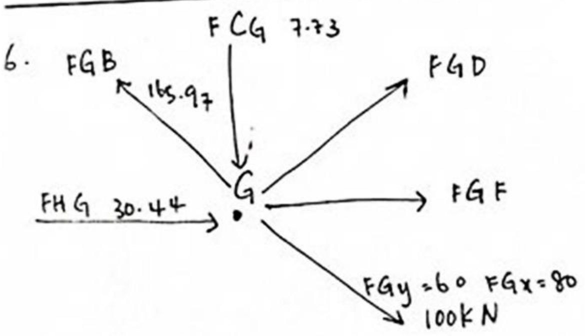
$0 = -15.465 + FCDx$

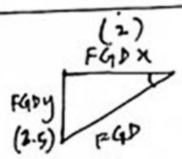
$FCDx = 15.465$

$FCD \cos 26.57° = 15.465$

$FCD = 17.291\ kN$

6.





$\tan\theta = \frac{2.5}{2}$

$\theta = 51.34°$

$\sin 51.34 = \frac{FGDy}{FGD}$

① ——— $FGDy = FGD \sin 51.34°$

$\cos 51.34° = \frac{FGDx}{FGD}$

② ——— $FGDx = FGD \cos 51.34°$

$\Sigma Fx = 0$

$0 = 30.44 - 124.90 - 33.29 + FGDx + 80 + FGF$

$0 = -14.46 - FGDx + FGF$

$0 = -14.46 - FGD\ 0.625 + FGF$

$FGD\ 0.625 = FGF - 14.46$

$FGF = 48\ kN$

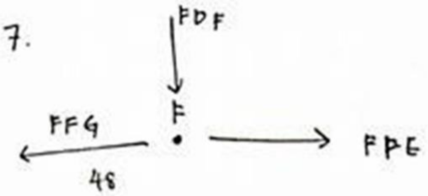
$\Sigma Fy = 0$

$0 = 109.30 - 7.73 + FGDy - 60$

$0 = 41.57 + FGDy$

$FGD = -53.29\ kN$

7.



$\Sigma f x = 0$

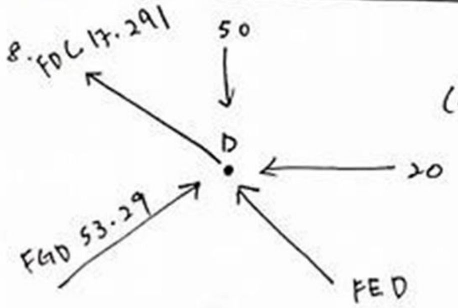
$0 = -48 + FFE$

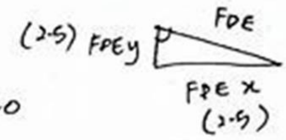
$FFE = 48 kN$ //

$\Sigma f y = 0$

$FDF = 0 kN$ //

8.





$\tan \theta = 1$

$\theta = 45°$

$\sin 45° = \frac{FDE x}{FDE}$

① ——— $FDE x = FDE \sin 45°$

$\cos 45° = \frac{FDE y}{FDE}$

② ——— $FDE y = FDE \cos 45°$

$\Sigma x = 0$

$0 = -20 - FDE x + 33.25 - 15.465$

$FDE X = -2.175$ ——— ③

$FDE \sin 45 = -2.175$

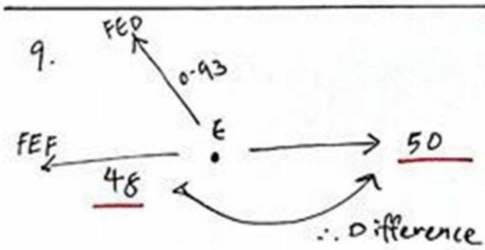
$FDE = -3.08 kN$ //

$FDE y = -3.08 \cos 45°$

$= -2.18$

same value .

9.



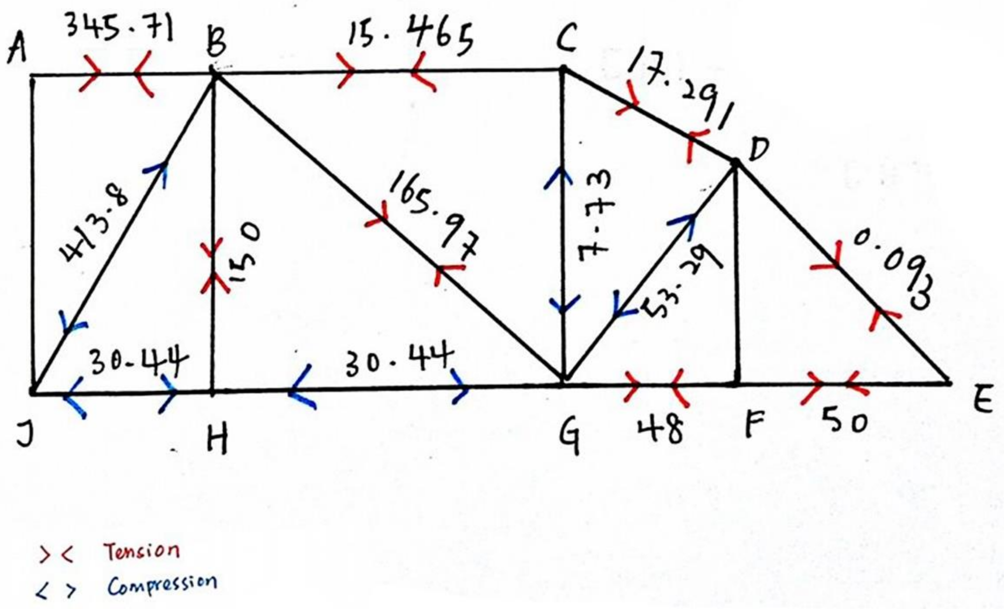
∴ Difference ② // .

$\Sigma Fy = -2.18$.

$\Sigma fx = -48 + 50 - 2.18$

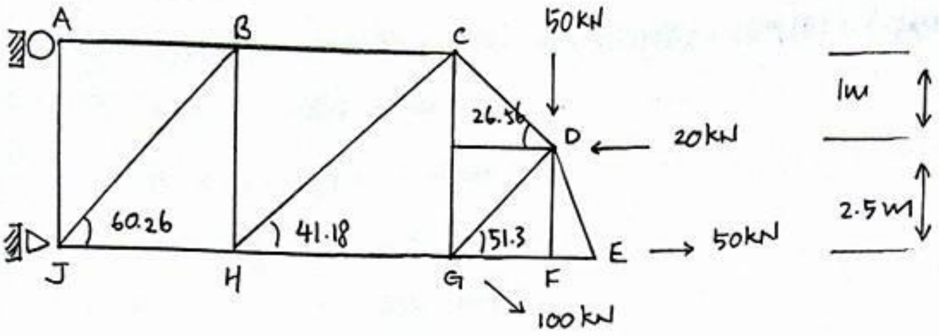
$\Sigma FX = -0.18$

∴ Difference = ② //


A
345.71
B
15.465
C
17.291
D
413.8
150
165.97
7.73
53.29
0.093
30.44
30.44
J
H
G
48
F
50
E
>< Tension
<> Compression

CASE STUDY 5

CHEAH HOONG FEI (0311690)



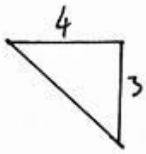
1. Determine perfect truss

$2J = m + 3$

$2(9) = 15 + 3$

$18 = 18$ * It is a perfect truss.

2 Determine reaction force



$\tan g = \frac{4}{3}$

$g = 53.13$

* $Gx = 100 \sin Q$

$= 80kN$

$Gy = 100 \cos Q$

$= 60kN$

$\Sigma fx = 0$

$-RAx - Rjx - 50 - 80 + 20 = 0$

$RAx + Rjx = -110 kN$ — (1)

$\Sigma fy = 0$

$-100 - 50 - 60 - 150 + Rjy = 0$

$Rjy = 360kN$

$\Sigma M = 0$

$3.5 R_{Ax} + 100(2) + (150)(2) + (50)(8) + (60)(6) + (-20)(2.5)$

$R_{Ax} = -345.71$ kN

* $R_{Ax} + R_{Jx} = -110$ kN

$R_{Jx} = -110 + 345.71$

$= 235.71$ kN

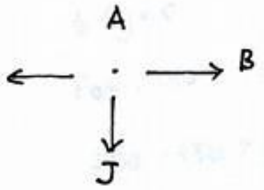
Joint A

$\Sigma f_x = 0$

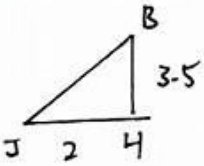
$-F_{ax} - F_{ab} = 0$

$F_{ab} = 345.71$ kN

* F_{ab} is a tension.



Joint J



$\tan Q = \frac{3.5}{2}$

$Q = 60.26$

$\Sigma f_y = 0$

$F_{JA} + F_{Jy} + F_{BJ} \sin Q = 0$

$F_{BJ} \sin Q = -360$

$F_{BJ} = -414.6$ kN

* F_{BJ} is a compression

$\Sigma F_x = 0$

$F_{Jx} + F_{JA} + F_{JB} \cos Q = 0$

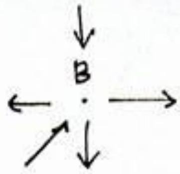
$F_{JH} = -F_{Jx} - F_{JB} \cos Q$

$= -235.71 + 205.67$

$= -30.04$ kN

* F_{JH} is compression

Joint B



$\Sigma f_x = 0$

$-F_{AB} + F_{BC} + F_{BJ} \cos Q = 0$

$-345.71 + F_{BC} + 206.67 = 0$

$F_{BC} = 140.04$ kH

* F_{BC} is tension

$\Sigma f_y = 0$

$-100 - F_{BH} + F_{BJ} \sin Q = 0$

$-F_{BH} = 100 - F_{BJ} \sin Q$

$= 100 - 360$

$F_{BH} = 260$ kN

* F_{BH} is tension

Joint H

$\Sigma f_x = 0$

$F_{JH}' + F_{HG} + F_{HC} \cos Q = 0$

$30.04 + F_{HG} + F_{HC} \cos Q = 0$

$F_{HG} + F_{AC} \cos Q = -30.04$ —(1)

$F_{HG} = -30.04 + 125.74$

$= 95.704$

* F_{HG} is tension

$\Sigma f_y = 0$

$F_{BH} - 150 + F_{CH} \sin Q = 0$

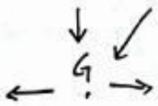
$260 - 150 + F_{CH} \sin Q = 0$

$F_{CH} \sin Q = -110$

$F_{CH} = -167.07$

* F_{CH} is Compression

Joint G



$\Sigma f_x = 0$

$F_{GH} + F_{GF} + 80 + F_{GD} \cos Q - 95.7$

$+ F_{GF} + 80 + F_{GD} \cos Q = 0$

$F_{GF} + F_{GD} \cos Q = -15.7$ kH —(1)

* $F_{GF} = 49.98$ kH

F_{GF} is tension

$\Sigma f_y = 0$

$-60 + F_{CG} + F_{GD} \sin Q = 0$

$F_{GD} \sin Q = 60 - 102.85$

$F_{GD} \sin Q = -42.85$

* $F_{GD} = -54.87$ kN

F_{GD} is compression

Joint F

$\Sigma F_x = 0$

$-F_{GF} + F_{FE} = 0$

$F_{FE} = F_{GF}$

$= 50$

* F_{GF} / F_{FE} is tension

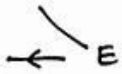
Joint E

$\Sigma F_x = 0$

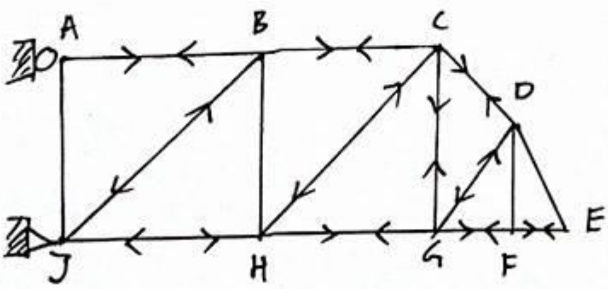
$-50 + F_{FE} - F_{ED} \cos Q = 0$

$-F_{ED} \cos Q = -F_{FE} + 50$

$= 0$ (in equilibrium)



Conclusion



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