ME 1110 – Engineering Practice 1

Engineering Drawing and Design - Lecture 17

Mechanical Elements
Space frames

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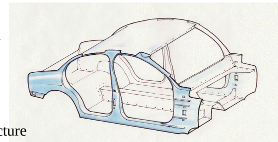
www.staff.city.ac.uk/~ra600/intro.htm

Facts about car structure

- **Chassis**
  - The most common type of structure used on the early cars 1900's
  - Still used on trucks & lorries, Black-Cab taxis
  - It provides structural platform onto which is mounted a body. Example: in the UK the Land Rover 'Defender' and 'Discovery'
- **Monocoque**
  - It is currently the standard structure for most cars made around the world in high volume production (100,000+per annum). First introduced by Budd in 1930's.
  - Constructed from pressed sheet steel, it combines the function of both chassis and body in a three dimensional structure.
  - In its purest sense, the term monocoque is applied to a structure which relies entirely on its outer skin for strength.
  - Most cars (except Jaguar E type) have additional stiffening elements – 'Semi-monocoque'
  - Lighter then chassis and easier to manufacture



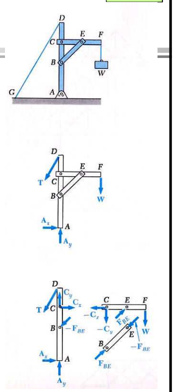
Facts about car structure - 2

- **Space frame**
  - Originally developed for performance cars such as Maserati in the early 1950's. as 'cage' of welded tubes onto which a non-structural body shell is attached.
  - The spaceframe, unlike the monocoque, relies on an internal tubular cage or frame to provide all the load bearing qualities of the vehicle.
  - Spaceframes are more labour intensive than the welded steel monocoque due a greater number of parts required in constructing the body.
  - The arrival of the Multipla and Audi A2 challenges the generally accepted view of a technology associated with expensive, low volume cars. For the first time a structure very close to that of a true spaceframe is going to be used to build medium volume production runs of around 50,000 units a year.
- **Composite**
  - Made out of two or more different materials that can be conveniently and easily formed. Lightweight, high strength, easy to manufacture,

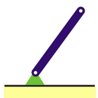
Frames -Definition

- Frames are structures that always contain at least one member acted on by forces at three or more points (***three or more force members***). Frames are constructed and supported so as to prevent any motion.
- Frame-like structures that are not fully constrained are called machines or mechanisms.
- Degrees of freedom: $F=3(n-1)-2f$

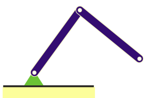
  n – total number of links
  f – total number of joints
- Frames have 0 degrees of freedom, machines have more



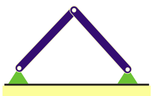
Degrees of freedom - example



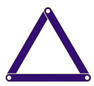
$n=2$, $f=1$, $F=3(2-1)-2\cdot 1=\mathbf{1}$



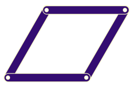
$n=3$, $f=2$, $F=3(3-1)-2\cdot 2=\mathbf{2}$



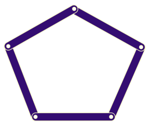
$n=3$, $f=3$, $F=3(3-1)-2\cdot 3=\mathbf{0}$



$n=3$, $f=3$, $F=3(3-1)-2\cdot 3=\mathbf{0}$



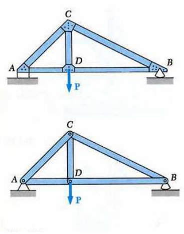
$n=4$, $f=4$, $F=3(4-1)-2\cdot 4=\mathbf{1}$



$n=5$, $f=5$, $F=3(5-1)-2\cdot 5=\mathbf{1}$

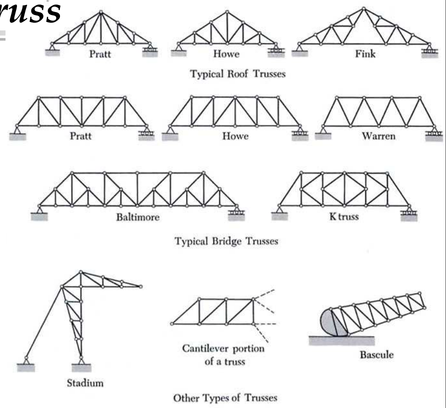
Trusses -Definition

- Trusses are special cases of frames. These are structures composed entirely of members that are loaded with forces in two points (***two force members***)
- These consist generally of triangular sub-element and are constructed and supported so as to prevent any motion.



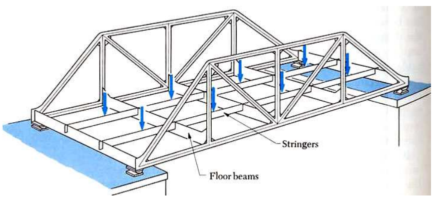
Planar Truss

Planar Trusses lie in a single plane and all applied loads must lie in the same plane.



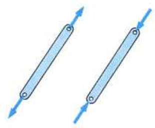
Space Truss

Space Trusses - are structures that are not contained in a single plane and/or are loaded out of the plane of the structure.



Truss

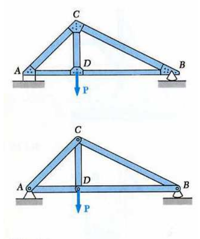
- There are four main assumptions made in the analysis of truss
  - The truss is made up of single bars, which are either in compression, tension or no-load.
  - Truss members are connected together at their ends only.
  - Truss are connected together by frictionless pins.
  - The truss structure is loaded only at the joints.
  - The weights of the members may be neglected.



2D Truss

The basic building block of a truss is a triangle. Large truss are constructed by attaching several triangles together A new triangle can be added truss by adding two members and a joint.

A truss constructed in this fashion is known as a ***simple truss***.



Simple 2D Truss

To determine if a 2D (*planar*) truss is solvable:

$$m=2{\cdot}j-3$$

m - number of members,
j - number of joints,
3 - represents the external support reactions

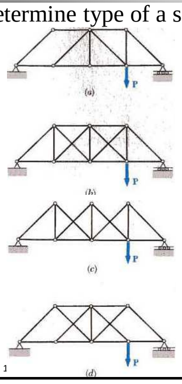
$m < 2{\cdot}j-3$ the truss is unstable and will collapse under load (*unstable*),

$m = 2{\cdot}j-3$ the truss is rigid and solvable (*determinate*),

$m > 2{\cdot}j-3$ the truss has more unknowns than equations and it is *indeterminate* structure.

Simple Truss- Identify

Determine type of a simple truss

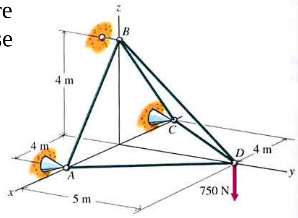


m=12		*j=8*		*unstable*
12	*<*	*2·8-3=13*		
m=15		*j=8*		*indeterminate*
15	*>*	*2·8-3=13*		
m=13		*j=8*		*determinate*
13	*<*	*2·8-3=13*		
m=13		*j=8*		*determinate*
13	*<*	*2·8-3=13*		

3D Truss

The difference between 2-D and 3-D truss is that there are three more equations because of the 3D nature of the problem.

A 3D truss if constructed only from triangles attached together is also a ***simple truss***.



Simple 3D Truss

To determine if a 3D (*space*) truss is solvable:

m=3·j-6

m - number of members,
j - number of joints,
6 - represents the external support reactions

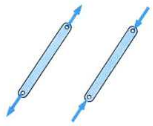
m < 3·j-6 the truss is unstable and will collapse under load (*unstable*),

m = 3·j-6 the truss is rigid and solvable (*determinate*),

m > 3·j-6 the truss has more unknowns than equations and it is *indeterminate* structure.

How to Calculate Truss?

- Forces in a Truss members can be calculated by:
  - *Methods of Joints*
  - *Methods of Sections*



- The method of joints

  employs the summation of forces at a joint to calculate forces in members.
  It does not use the moment equilibrium equation to solve the problem.

  Method is convenient if forces in all members are to be calculated. It will be explained in more details later.

$$\sum F_x = 0$$
$$\sum F_y = 0$$
$$\sum F_z = 0$$

How to Calculate Truss?

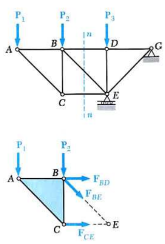
- The method of sections

  Convenient method if only the force in one member is required.

  In this method a cutting line is used to breakup the truss in two parts.

  Moment equation in the most convenient point is then used to calculate a force acting to the member of interest.

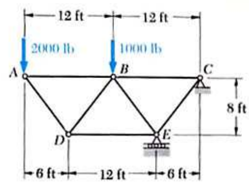
  Example, force acting in member CE:



$$\sum M_B = 0: \quad P_1 \cdot \overline{AB} + F_{CE} \cdot \overline{CB} = 0 \Rightarrow F_{CE} = -P_1 \frac{\overline{AB}}{\overline{CB}}$$

Method of Joints –Example

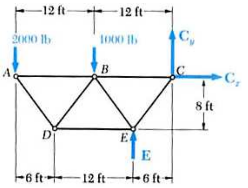
Using the method of joints, determine the force in each member of the planar truss.



Method of Joints –Example

Calculate restraint reactions

Draw the free body diagram of the truss and solve for the equations:



$$\sum F_x = 0: \quad C_x = 0$$

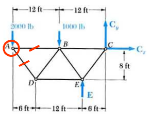
$$\sum F_y = 0: \quad 2000\text{-}1000 + E + C_y = 0 \Rightarrow E + C_y = 3000 \text{ lb}$$

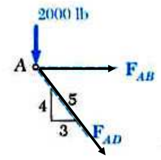
$$\sum M_C = 0: \quad 2000(24 \text{ ft}) + 1000(12 \text{ ft}) - E(6 \text{ ft}) \Rightarrow E = 10000 \text{ lb}$$

$$C_y = 3000 - 10000 = -7000 \text{ lb}$$

Method of Joints –Example

Joint A





$$\sum F_y = 0 = -\frac{4}{5} F_{AD} - 2000 \text{ lb}$$

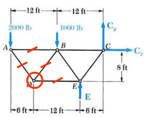
$$F_{AD} = -2500 \text{ lb} \Rightarrow \boxed{F_{AD} = 2500 \text{ lb } (C)}$$

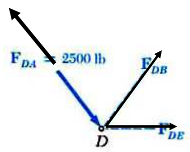
$$\sum F_x = 0 = \frac{3}{5} F_{AD} + F_{AB} = \frac{3}{5}(-2500 \text{ lb}) + F_{AB}$$

$$F_{AB} = 1500 \text{ lb} \Rightarrow \boxed{F_{AB} = 1500 \text{ lb } (T)}$$

Method of Joints –Example

Joint D





$$\sum F_y = 0 = \frac{4}{5} F_{AD} + \frac{4}{5} F_{DB} = \frac{4}{5}(-2500) + \frac{4}{5} F_{DB}$$

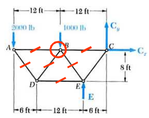
$$F_{DB} = 2500 \text{ lb} \Rightarrow \boxed{F_{DB} = 2500 \text{ lb}(T)}$$

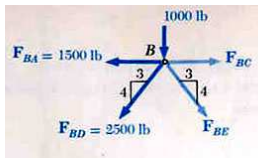
$$\sum F_x = 0 = -\frac{3}{5} F_{AD} + \frac{3}{5} F_{DB} + F_{DE} = \frac{-3}{5}(-2500) + \frac{3}{5}(2500) + F_{DE}$$

$$F_{DE} = -3000 \text{ lb} \Rightarrow \boxed{F_{DE} = 3000 \text{ lb}(C)}$$

Method of Joints –Example

Joint B





$$\sum F_y = 0 = -\frac{4}{5} F_{BD} - \frac{4}{5} F_{BE} - 1000 = -\frac{4}{5}(2500) - \frac{4}{5} F_{BE} - 1000$$

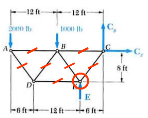
$$F_{BE} = -3750 \text{ lb} \Rightarrow \boxed{F_{BE} = 3750 \text{ lb } (C)}$$

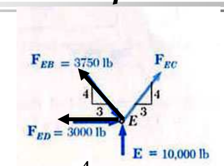
$$\sum F_x = 0 = -\frac{3}{5} F_{BD} - F_{BA} + \frac{3}{5} F_{BE} + F_{BC} = \frac{-3}{5}(-2500) - 1500 + \frac{3}{5}(-3750) + F_{BC}$$

$$F_{BC} = 5250 \text{ lb} \Rightarrow \boxed{F_{BC} = 5250 \text{ lb } (T)}$$

Method of Joints –Example

Joint E





$$\sum F_y = 0 = -\frac{4}{5} F_{EB} + \frac{4}{5} F_{EC} + E = -\frac{4}{5}(-3750) + \frac{4}{5} F_{DE} + 10000$$

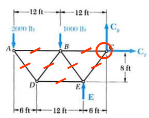
$$F_{EC} = -8750 \text{ lb} \Rightarrow \boxed{F_{EC} = 8750 \text{ lb } (C)}$$ *(maximum load)*

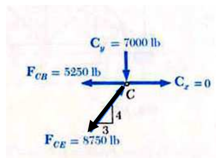
$$\sum F_x = 0 = -\frac{3}{5} F_{EB} - F_{ED} + \frac{3}{5} F_{EC} = -\frac{3}{5}(-3750) - (-3000) + \frac{3}{5} F_{EC}$$

$$F_{EC} = -8750 \text{ lb} \Rightarrow F_{EC} = 8750 \text{ lb } (C)$$ *(check the solution)*

Method of Joints –Example

Joint C





(check the solution)

$$\sum F_y = 0 = -\frac{4}{5} F_{CE} - C_y = -\frac{4}{5}(-8750) - 7000 = 0$$

$$\sum F_x = 0 = -\frac{3}{5} F_{CE} - F_{CB} + C_x = -\frac{3}{5}(-8750) - 5250 = 0$$

COMPETITION: Load/weight ratio
Winner 20 extra marks

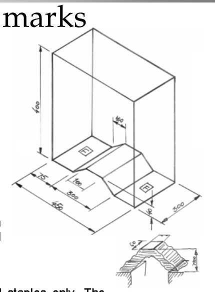
City University London
School of Engineering and Mathematical Sciences

Engineering Drawing and Design, EM 1105 (EM1.5)

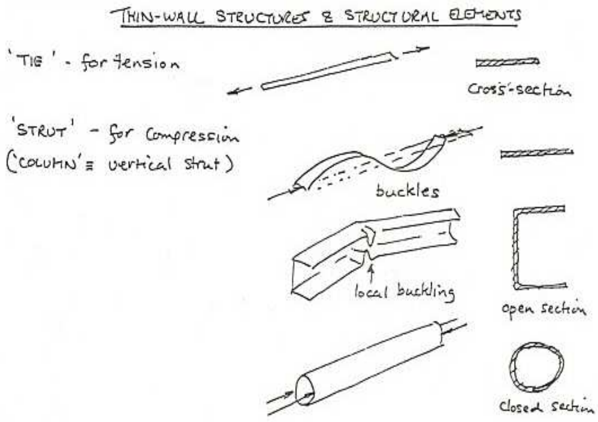
Exercise code: DeP-3 (*exercise 10*)
Exercise type: Group Design, Build and Test Project
Exercise title: Paper structure

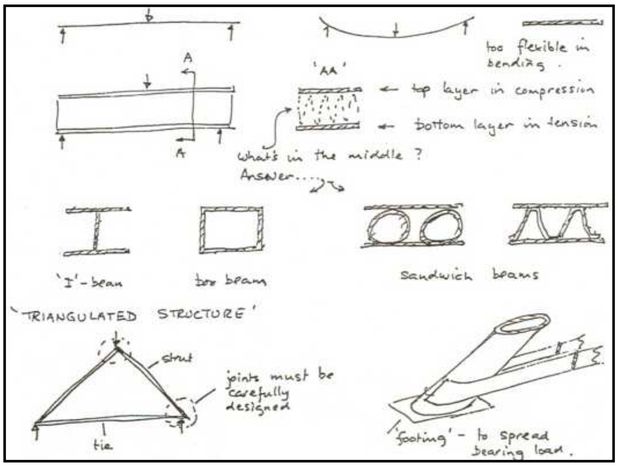
Exercise Assignment:

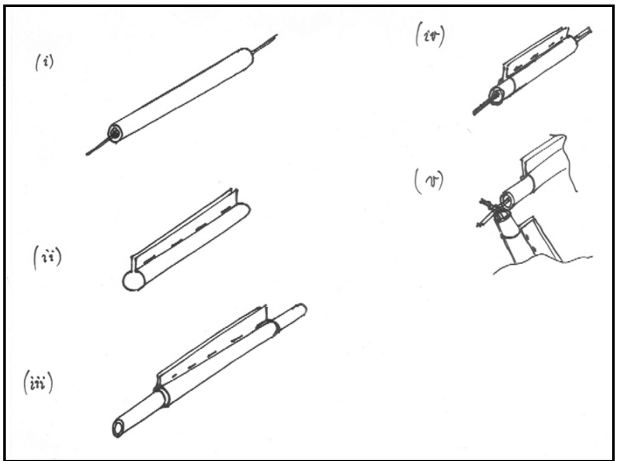
Task (Objective):
Design, build and test a papers structure to span a gap of 300 mm, which can carry a concentrated load at its middle span on the platform.



Specification:
The structure is to be made of drawing paper and staples only. The structure must bridge the over the gap 300 mm long. Structure must be completely contained in the volume shown in the figure. Feet of the structure must be completely contained within the areas F. Load area of the structure must be at least 60x60 mm and must not be less than 100 mm higher then the level of areas F. Dimensions of the volume within which the structure must be contained are given in the following figure.







Last Year Winner