MIM 271E THEORY OF STRUCTURES

WEEK 2

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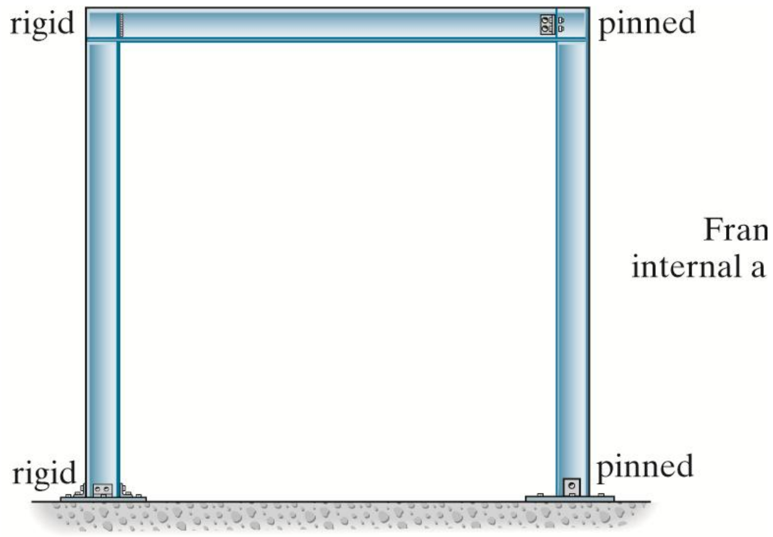
Principles of Structural Analysis

The main topic of MIM 271E Theory of Sturctures is the structural analysis of ***two-dimensional lineer*** statically ***determinate*** and ***indeterminate*** structures.

Structural Forms

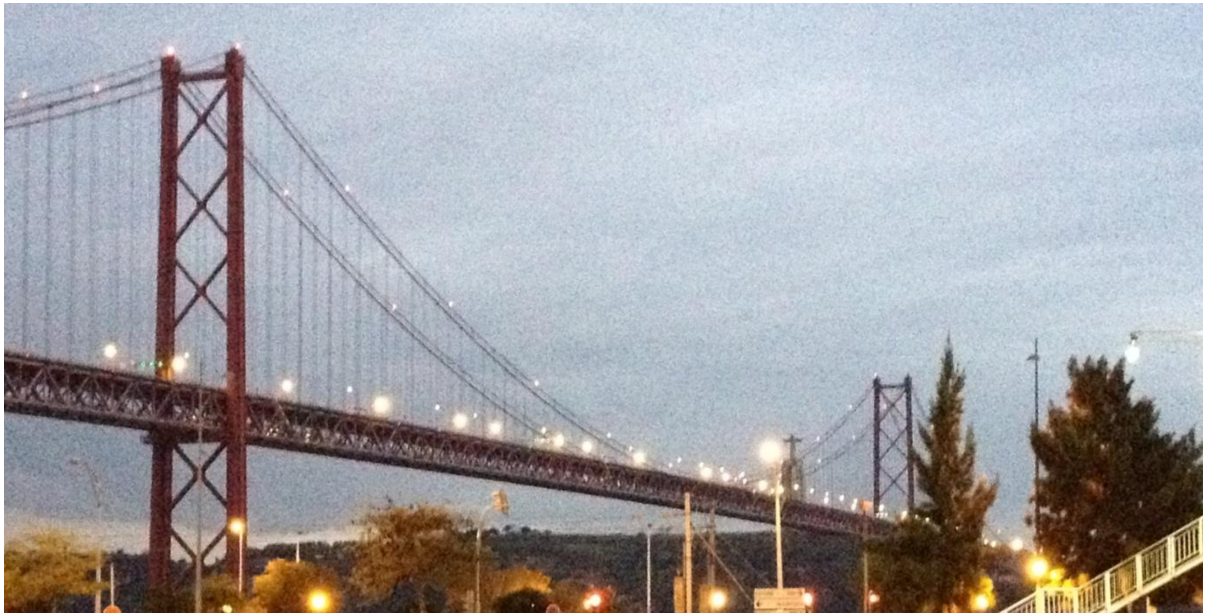
simply supported beam

Structural Forms



frames

cables



Structural Forms

arches

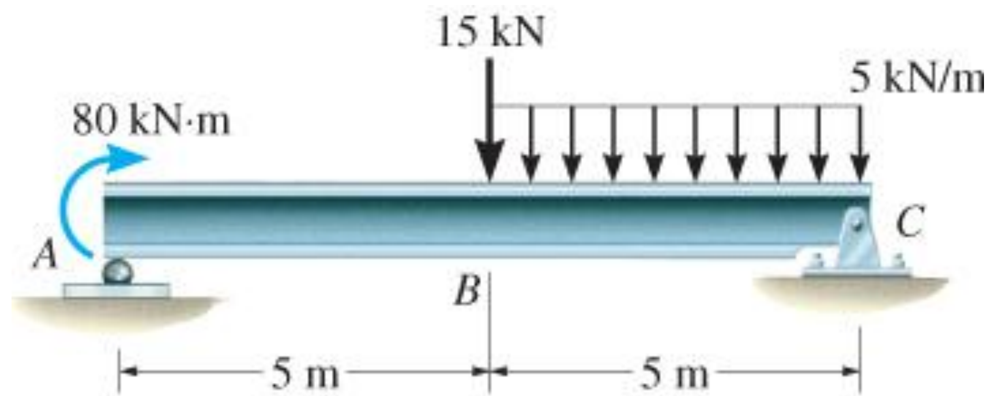
trusses

Structural Forms

Loads

Classifications:

– Concentrated Load, Distributed Load



– Static Load, Dynamic Load

– Dead Load, Live Load

Dead and live loads are combined according to the selected analysis method and national code specifications. Eventually, combined load (P) is applied to the idealized model of structure for structural analysis.

Loads

Loads to be supported by the structure should be determined.

Design loading for a structure is often specified in codes for every country.

Turkish

- Design codes

(TS498- Yapı Elemanlarının Boyutlandırılmasında Alınacak Yüklerin Hesap Değerleri - Design Loads For Buildings)

TS498 is not applicable to special structures as bridges, industrial structures etc.

- Seismic design code

(Specifications for Buildings to be Built in Seismic Zones, 2007)

Loads

Building and design codes for USA.

TABLE 1–1 Codes

General Building Codes
Minimum Design Loads for Buildings and Other Structures, ASCE/SEI 7-10, American Society of Civil Engineers
International Building Code
Design Codes
Building Code Requirements for Reinforced Concrete, Am. Conc. Inst. (ACI)
Manual of Steel Construction, American Institute of Steel Construction (AISC)
Standard Specifications for Highway Bridges, American Association of State Highway and Transportation Officials (AASHTO)
National Design Specification for Wood Construction, American Forest and Paper Association (AFPA)
Manual for Railway Engineering, American Railway Engineering Association (AREA)

Loads

- **Dead loads (G)**
  - Weights of various structural members (beams, columns, shear walls, slabs...)
  - Weights of any objects that are attached to the structure (plaster, floorings, levelling concrete layer...)

- **Live loads (Q)**
  - Varies in magnitude & location (people, furnitures, vehicles, cranes, snow, wind...)
  - Depends on the purpose for which the structure.
    - These loadings are generally tabulated in local, state or national codes.

TS498 - Design Loads For Buildings /Table 7. Vertical Uniform Distributed Live Load Values

ÇİZELGE 7 - Düzgün Yayılı Düşey Hareketli Yük Hesap Değerleri

Kullanma Şekli				Hesap Değeri
	ÇATILAR Yatay veya 1/20'ye kadar eğimli	Döşemeler	MERDİVENLER (Sahanlık ve merdiven girişi dahil)	kN/m^2
1		Çatı arası odalar		1,5
2	Zaman zaman kullanılan çatılar	Konut, teras oda ve koridorlar, bürolar, konutlardaki 50 m^2'ye kadar olan dükkanlar, hastane odaları		2
	ÇATILAR Yatay veya 1/20'ye kadar eğimli	Döşemeler	MERDİVENLER (Sahanlık ve merdiven girişi dahil)	Hesap Değeri kN/m^2
3	Konut toleranslarının kullanılması ve çiçeklik (bahçe yapılması)	Hastanelerin mutfakları, muayene odaları, poliklinik odaları, sınıflar, yatakhaneler, anfiler	Konut Merdivenleri	3,5
4		– Camiler – Tiyatro ve sinemalar, – Spor dans ve sergi salonları, – Tribünler (oturma yeri sabit olan) – Toplantı ve bekleme salonları – Mağazalar, – Lokantalar – Kütüphaneler – Arşivler – Hafif ağırlıklı atölyeler – Büyük mutfaklar, kantinler – Mezbahalar – Fırınlar, – Büyükbaş hayvan ahırları – Balkonlar 10 m^2'ye kadar – Büro, hastane okul, tiyatro sinema kütüphane depo vb. genel yapı koridorları	Umuma açık yapılarda büro hastane okul, tiyatro, kütüphane kitaplık vb.	5
5		– Tribünler (oturma yeri sabit olmayan)		7,5
6		– Garajlar (Toplam ağırlığı 2,5 tona kadar olan araçlar için)		5

Loads

Types of live loads

- Building loads
- Snow loads
- Hydrostatic & Soil Pressure

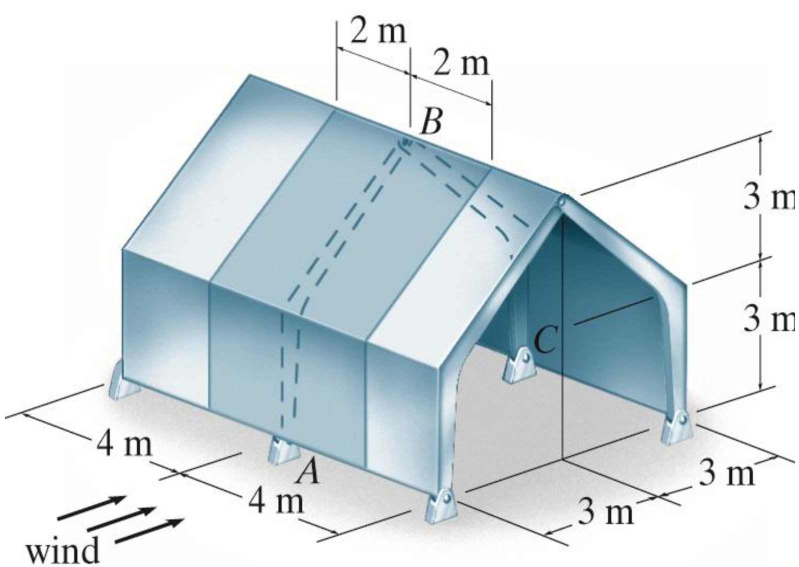
  E.g. tanks, dams, ships, bulkheads & retaining walls
- Highway Bridge loads
- Railway Bridge loads
- Impact loads
- Other natural loads
  - Effect of blast
  - Temperature changes
  - Differential settlement of foundation

Loads

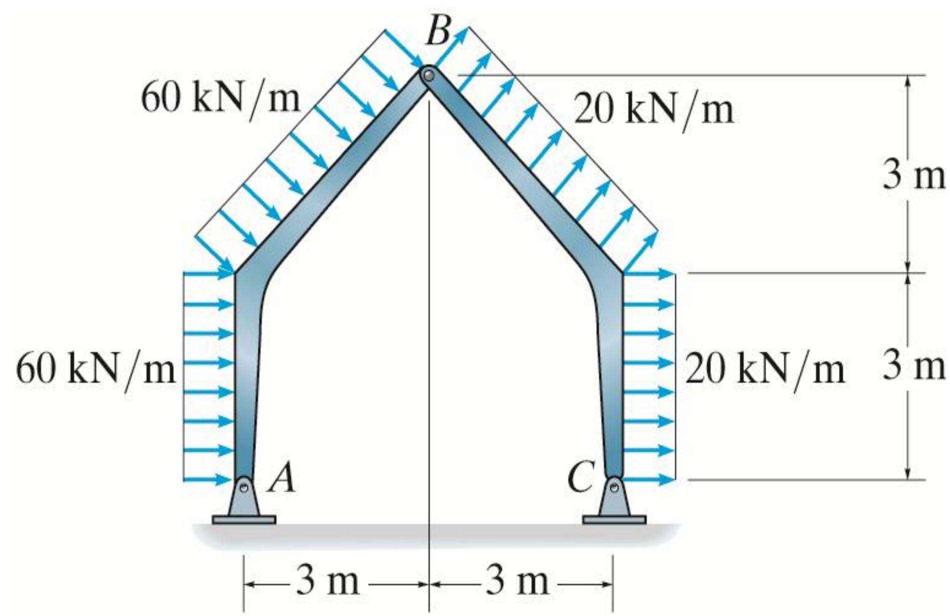
Types of live loads

– Wind loads

The side of the building is subjected to a wind loading that creates a uniform normal pressure on the windward side and a suction pressure of on the leeward side.



(a)



Loads

Earthquake loads

Earthquake produce loadings through its interaction with the ground & its response characteristics

Their magnitude depends on amount & type of ground acceleration, mass & stiffness of structure

During earthquake, the ground vibrates both horizontally & vertically

Structural Idealization

- To develop the ability to model or idealize a structure so that the structural engineer can perform a practical force analysis of the members

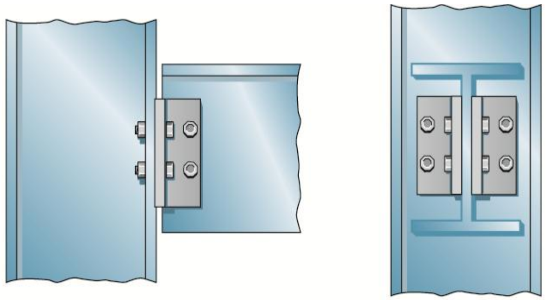
Support Connections: In reality, all connections exhibit some stiffness toward joint rotations owing to friction & material behavior

Pin connection (allows some freedom for slight rotation)

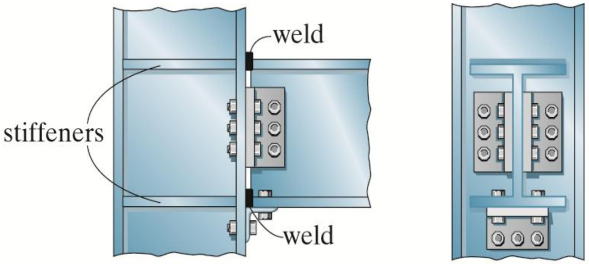
Roller support (allows some freedom for slight rotation)

Fixed joint (allows no relative rotation)

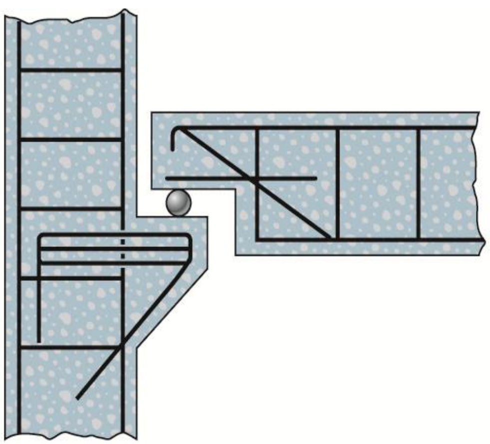
Structural Idealization



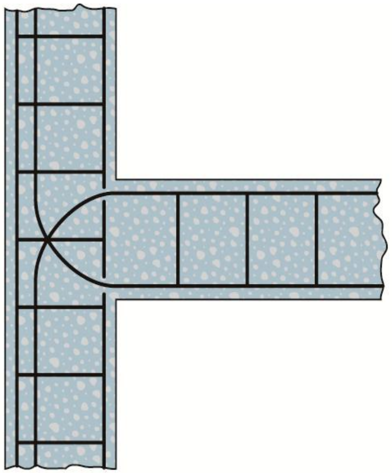
typical "pin-supported" connection (metal)



typical "fixed-supported" connection (metal)

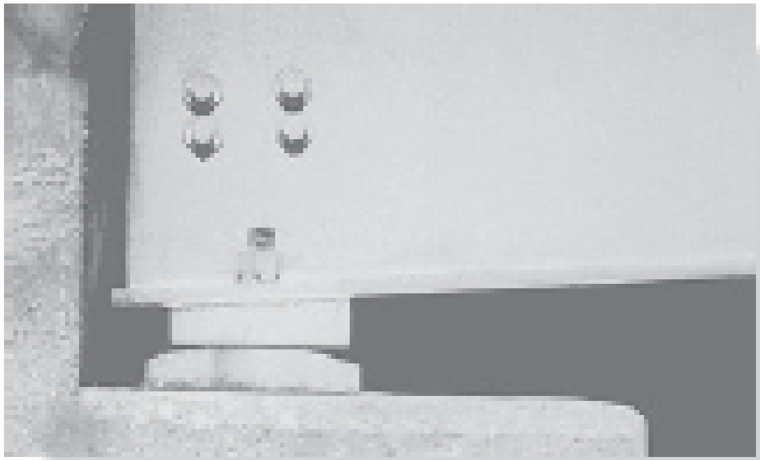


typical "roller-supported" connection (concrete)



typical "fixed-supported" connection (concrete)

Structural Idealization



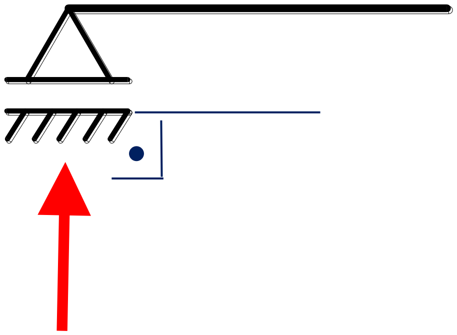
A typical rocker support used for a bridge girder.

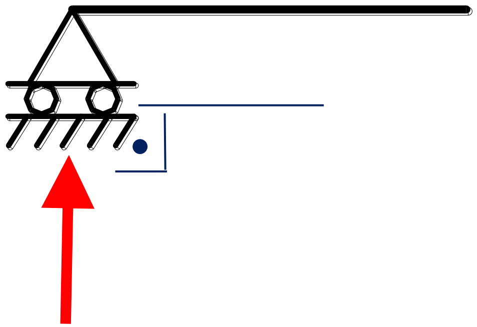
Typical pin used to support the steel girder of a railroad bridge.

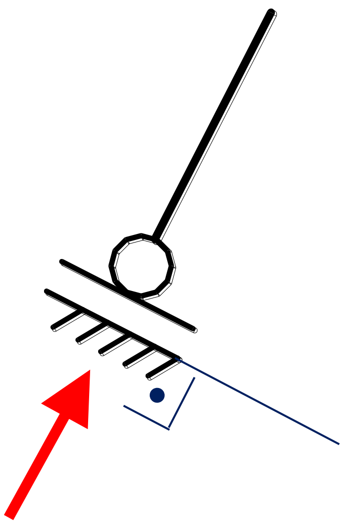
Structural Idealization

Idealization of Supports

Roller support





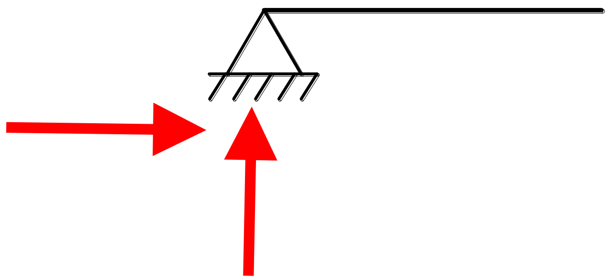


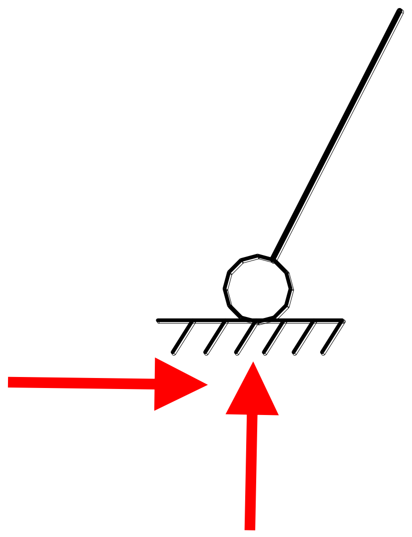
Support reaction = 1

Structural Idealization

Idealization of Supports

Simple support



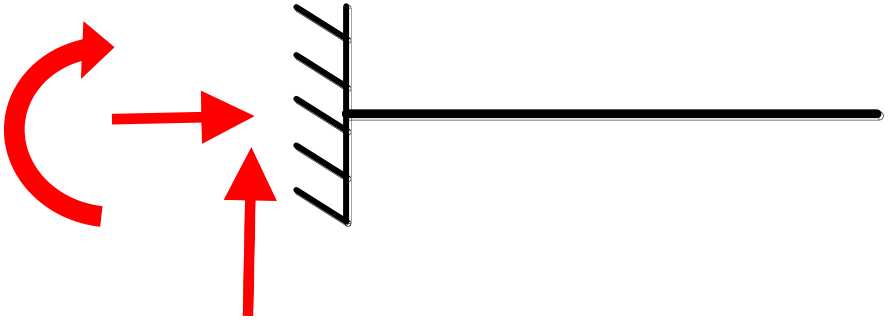


Support reaction = 2

Structural Idealization

Idealization of Supports

Fixed support

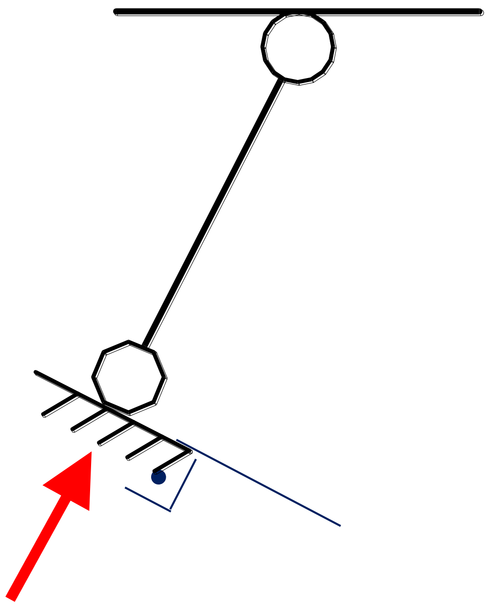


Support reaction = 3

Structural Idealization

Idealization of Supports

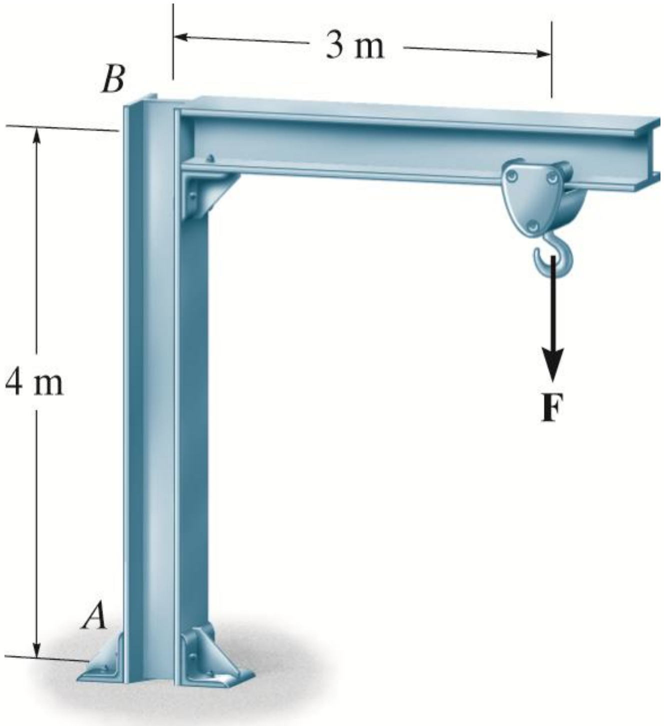
2-hinged element



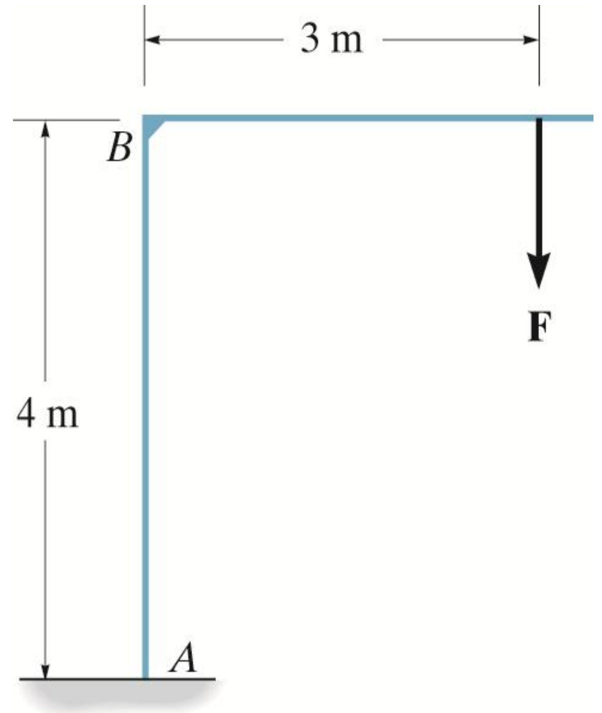
Support reaction = 1

Structural Idealization

- Consider the jib crane & trolley, we neglect the thickness of the 2 main member & will assume that the joint at B is fabricated to be rigid
- The support at *A* can be modeled as a fixed support



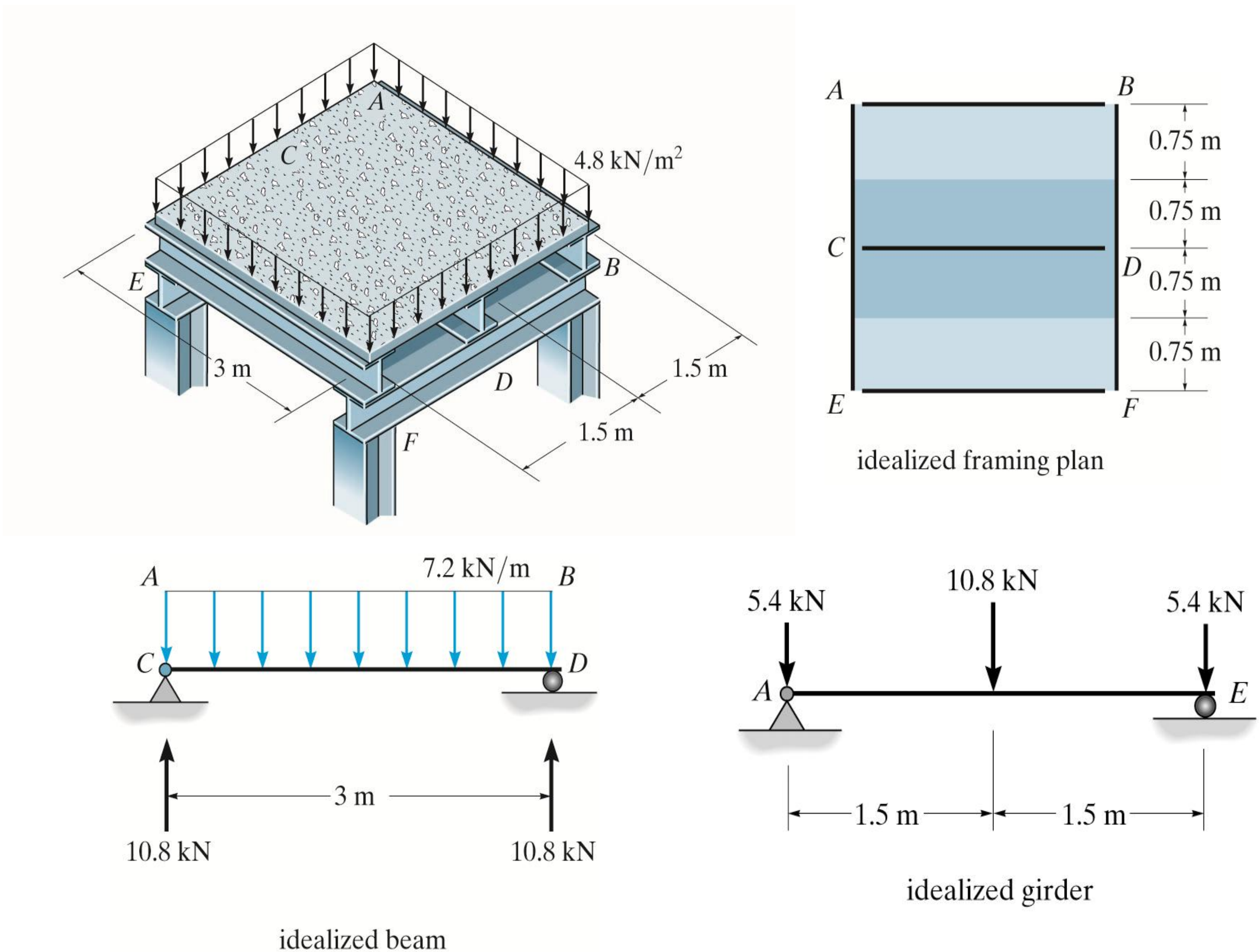
actual structure



idealized structure

Tributary Loadings

1-way system



idealized framing plan

idealized beam

idealized girder

Determinacy

Equilibrium equations provide both the necessary and sufficient conditions for equilibrium. All unknown forces can be determined strictly from these equations.

- For a coplanar system equations of equilibrium are,

$$\Sigma X = 0$$

$$\Sigma Y = 0$$

$$\Sigma M = 0$$

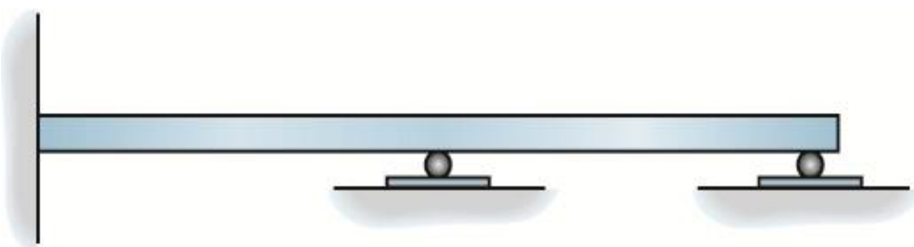
No. of unknown forces **=** equilibrium equation statically determinate

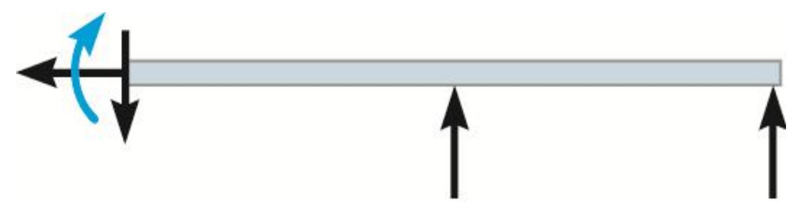
No. of unknown forces **>** equilibrium equation statically indeterminate

For statically indeterminate systems, additional equations needed to solve for the unknown equations and they are obtained as compatibility equations.

Determinacy

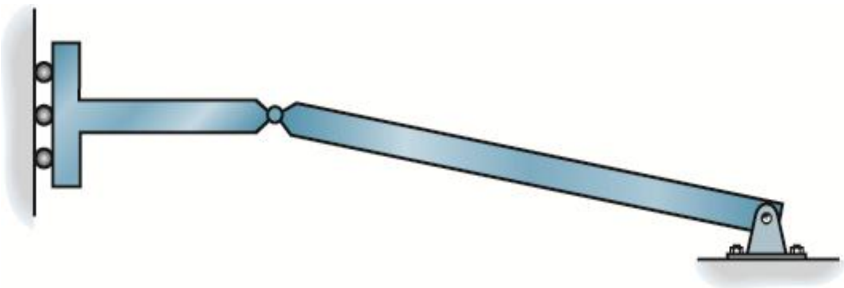
Statically determinate

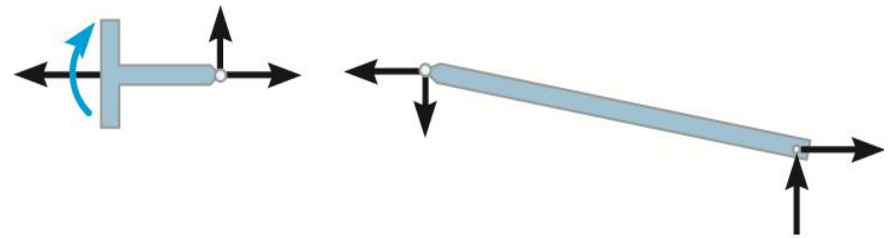




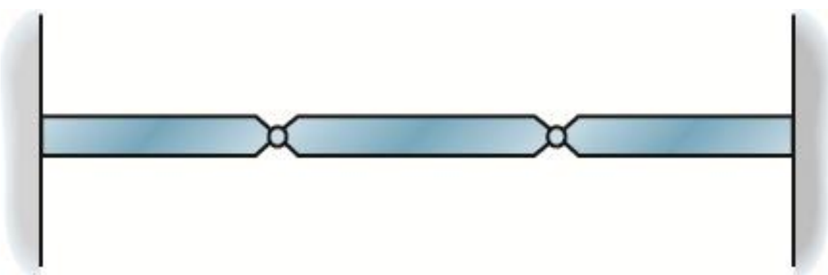
Statically indeterminate to
the second degree

Determinacy



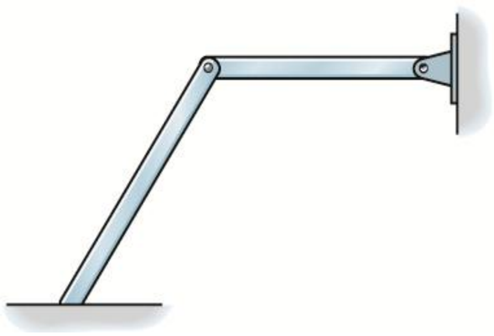


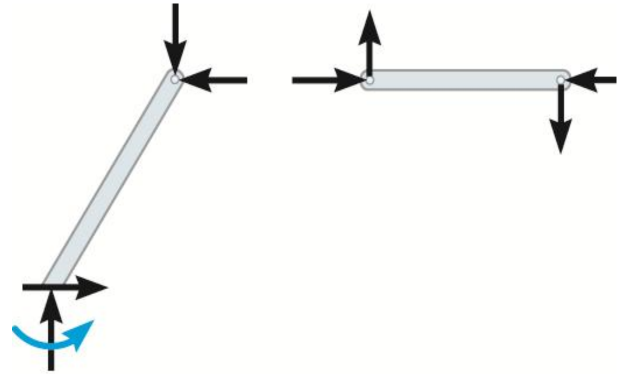
Statically determinate



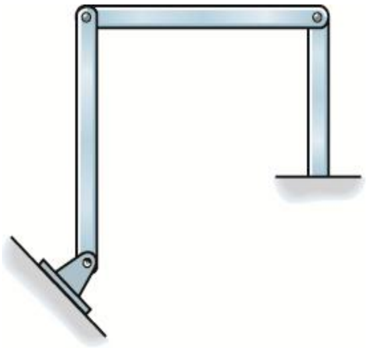
Statically indeterminate to the first degree

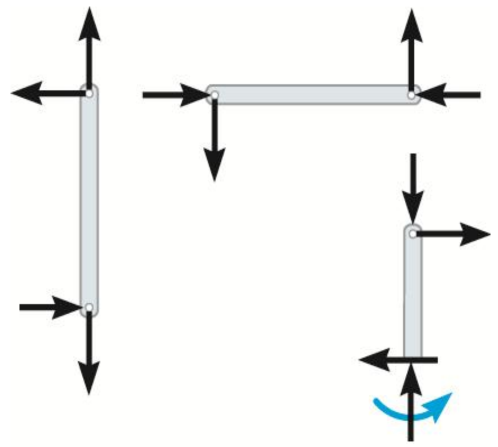
Determinacy



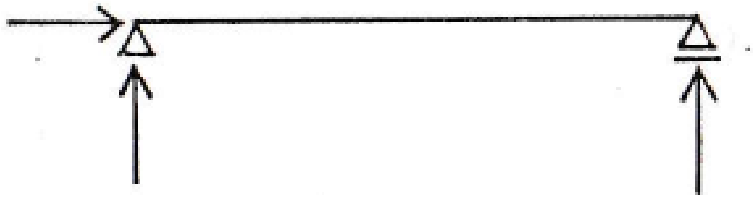


Statically indeterminate to the first degree

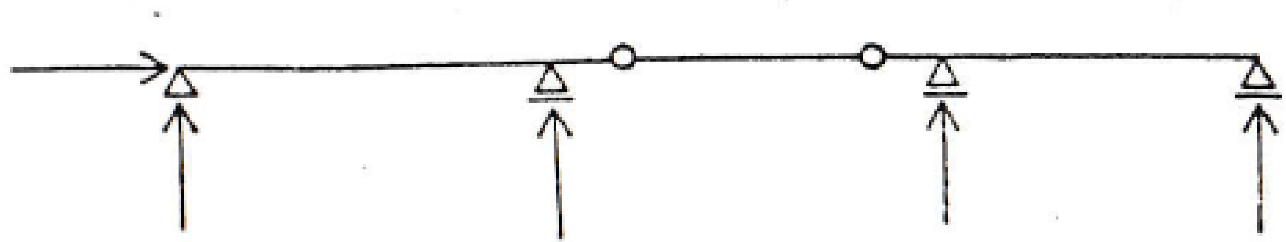




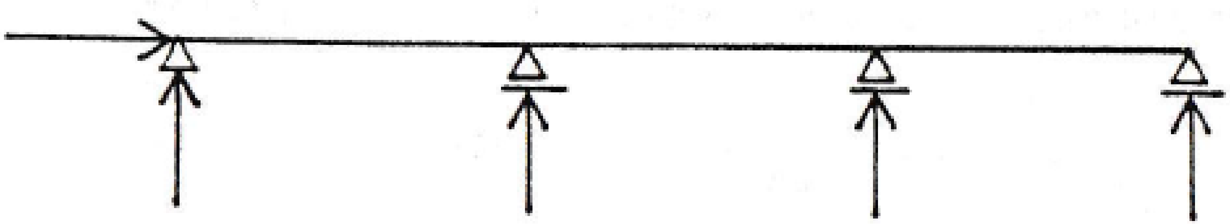
Statically determinate



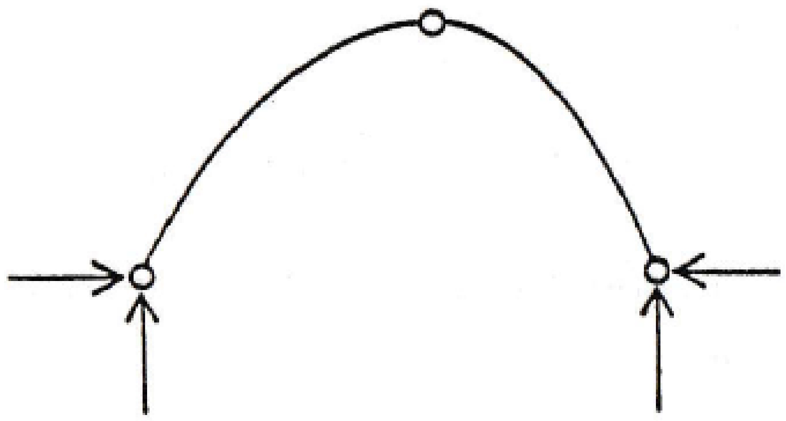
Simply supported beam



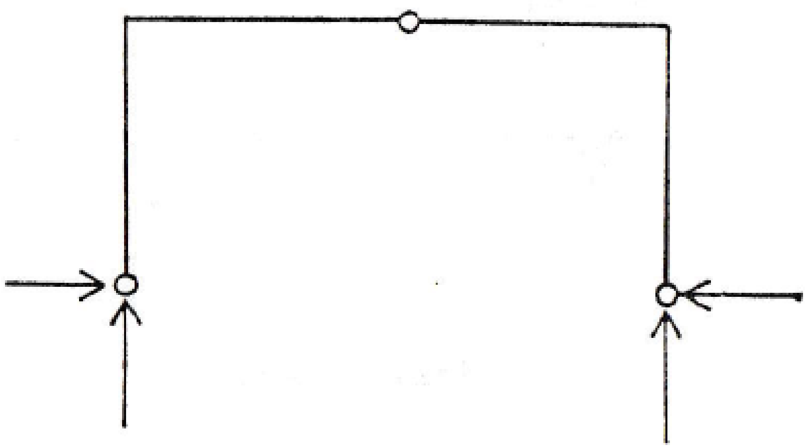
Continuous beam with hinges



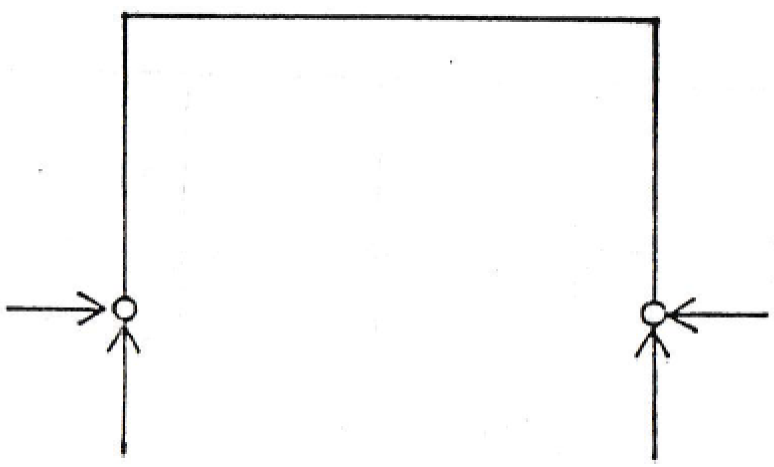
Continuous beam



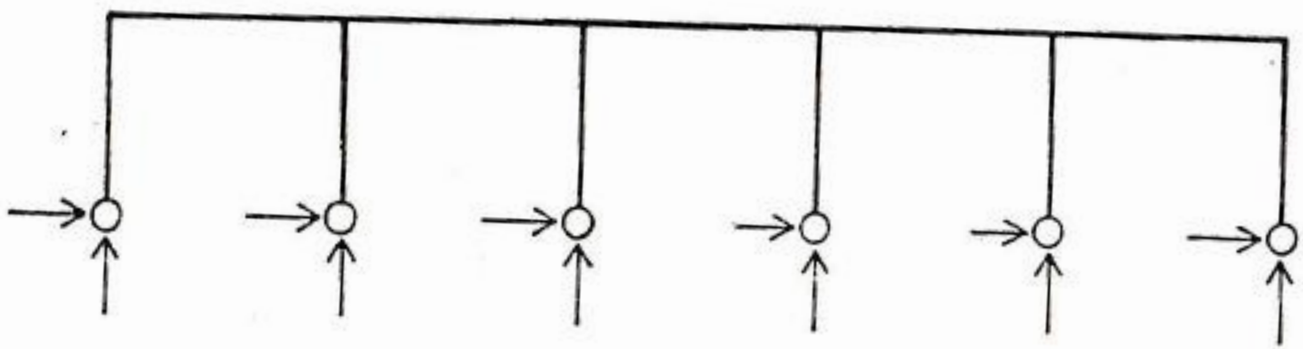
Three-hinged arch



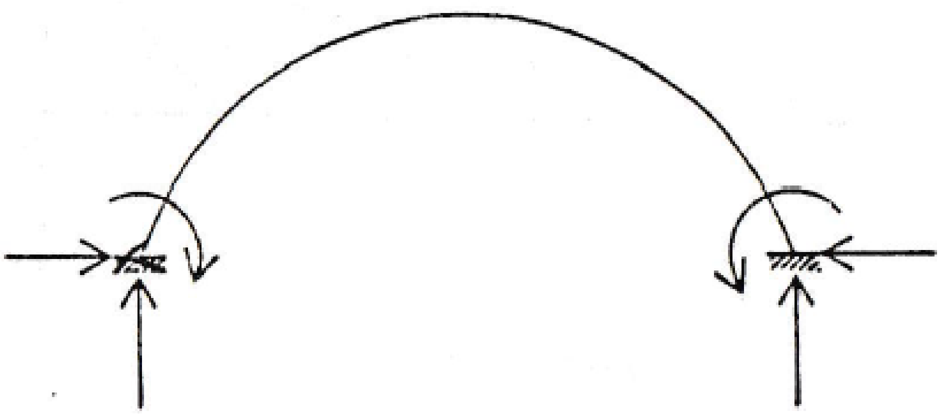
Three-hinged frame



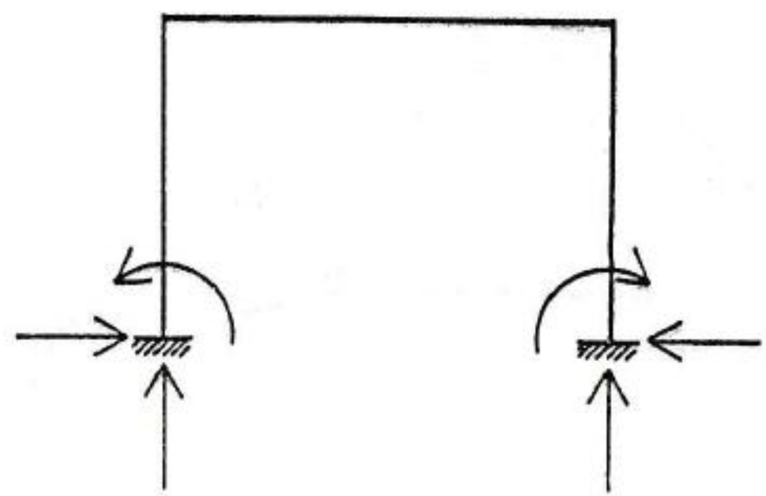
Single span hinged frame



Multi-span hinged frame

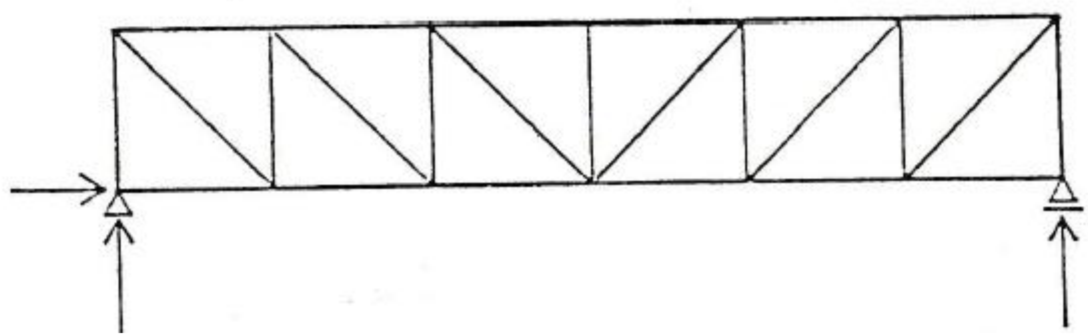


Arch

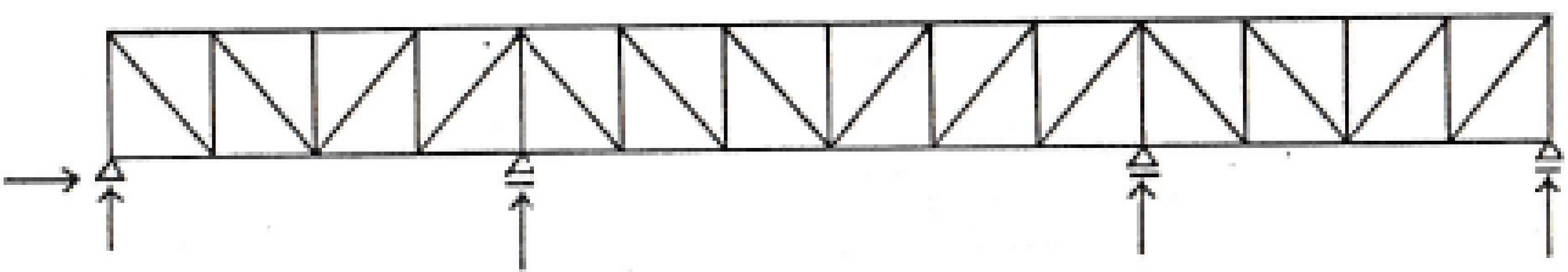


Frame

Trusses

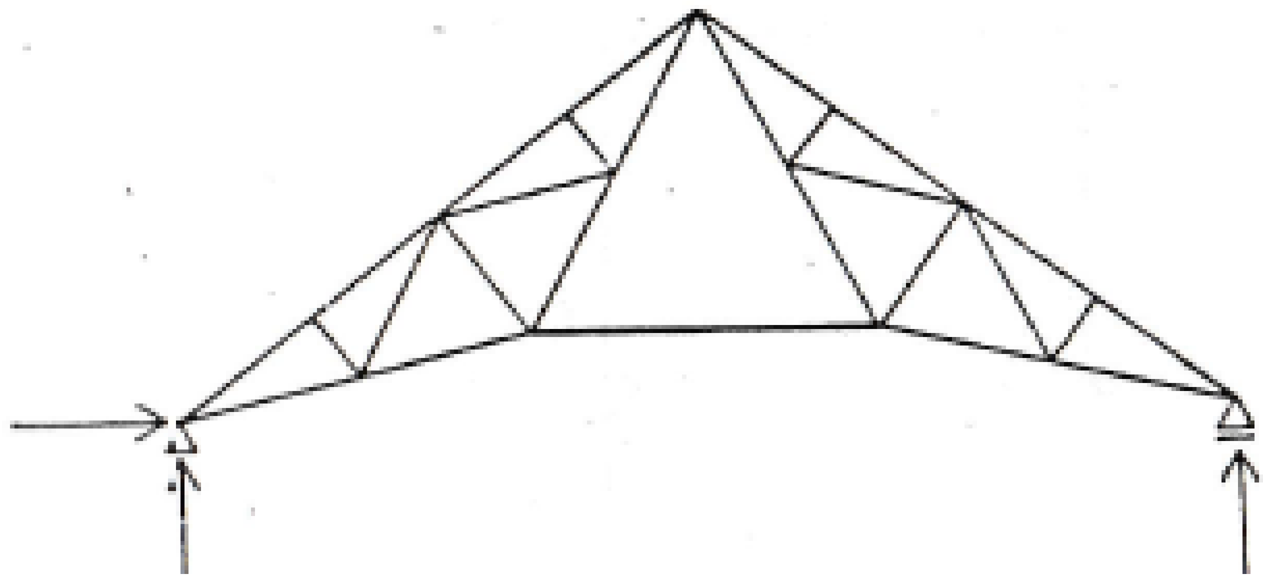


Simply supported truss



Multi-span truss

Trusses



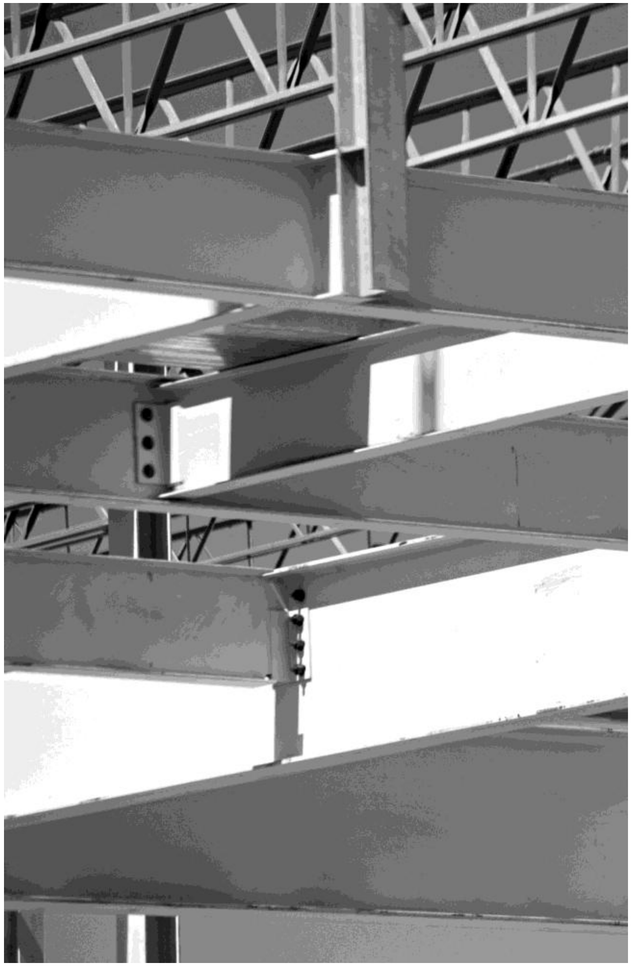
Simply supported roof truss

INTERNAL LOADINGS

N, T & M

Covered in Strength of

Materials



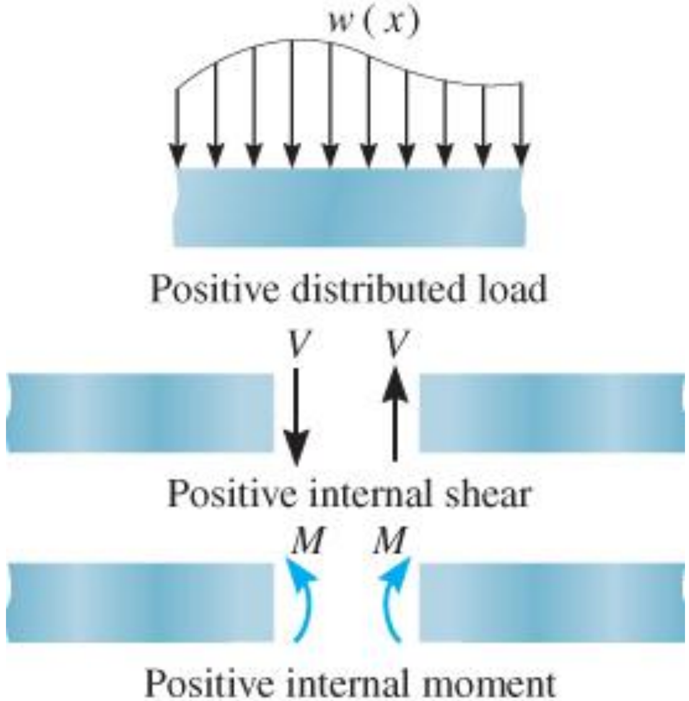
Normal Force, Shear and Moment Diagrams

- In order to design a structural element (beam and column), it is necessary to determine the maximum normal force, shear and moment in the element.
- Engineers need to know the *variation* of normal force, shear and moment (*normal*, *shear and moment diagrams)* along the beam to determine a cross-section and/or suitable structural material.
- To draw these graphs
  - First, obtain support reactions
  - Then, express **N, T** and **M** as functions of arbitrary position *x* along axis.

N, T, M Diagrams

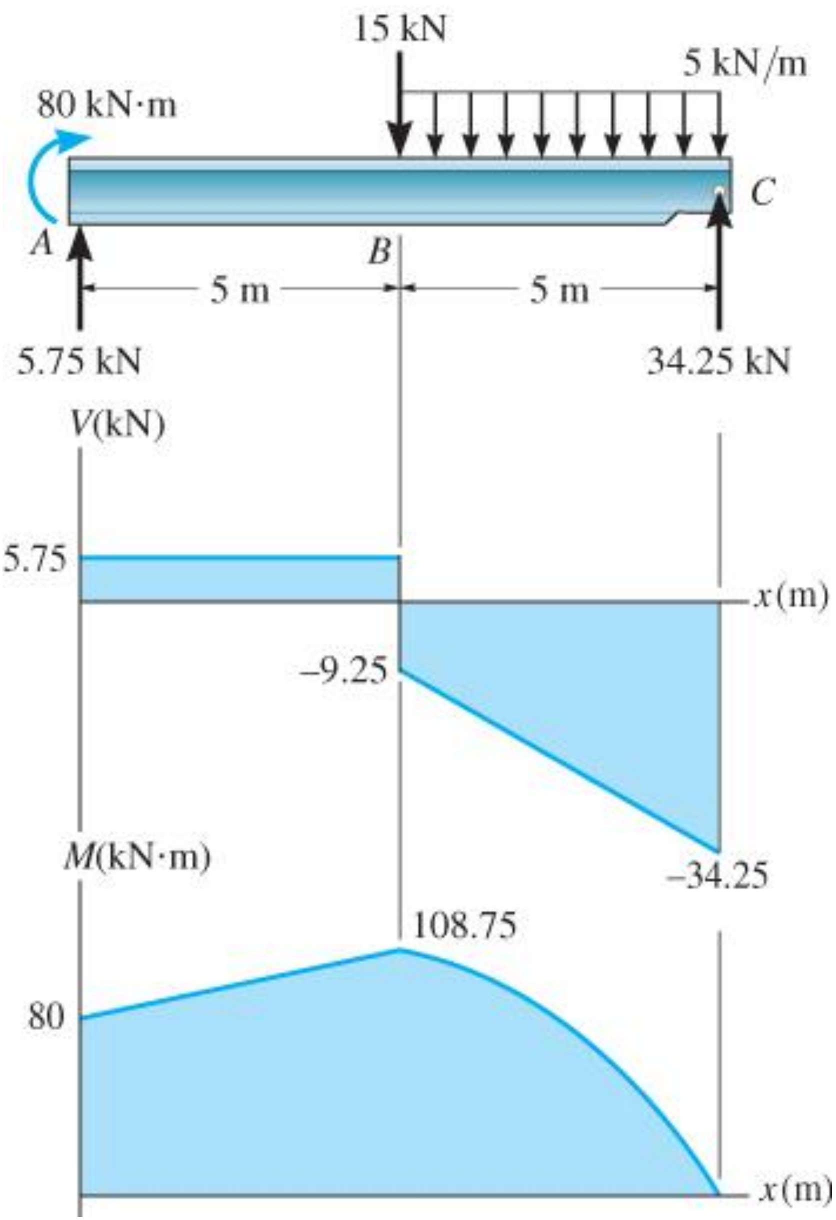
Sign convention

- Although choice of sign convention is arbitrary, in this course, we adopt the one often used by engineers:

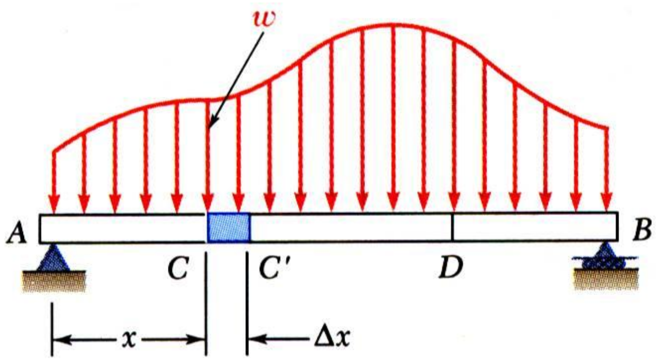


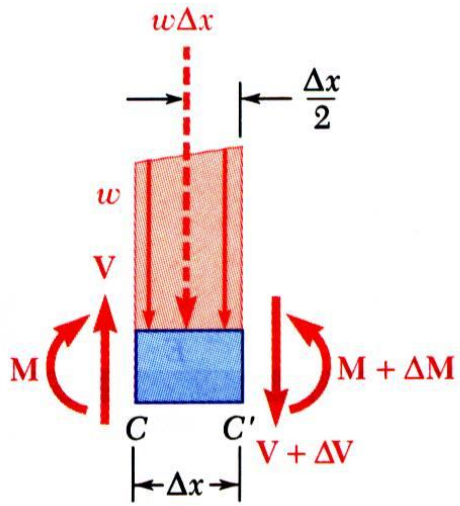
Example

Shear and moment diagrams



Relations Among Load, Shear Force, and Bending Moment





- Relations between load and shear force:

$$V-\left(V+\Delta V\right)-w\Delta x=0$$

$$\frac{dV}{dx}=\lim_{\Delta x\to 0}\frac{\Delta V}{\Delta x}=-w$$

$$V_D-V_C=-\int_{x_C}^{x_D} w\,dx$$

- Relations between shear and bending moment:

$$\left(M+\Delta M\right)-M-V\Delta x+w\Delta x\frac{\Delta x}{2}=0$$

$$\frac{dM}{dx}=\lim_{\Delta x\to 0}\frac{\Delta M}{\Delta x}=\lim_{\Delta x\to 0}\left(V-\tfrac{1}{2}w\Delta x\right)=V$$

$$M_D-M_C=\int_{x_C}^{x_D} V\,dx$$

Graphical Method for Constructing Shear and Moment Diagrams

Regions of distributed load

$$\frac{dV}{dx} = -w(x)$$

Slope of shear = – distributed load

$$\frac{dM}{dx} = V$$

Slope of moment = shear

$$\Delta V = -\int w(x)\, dx$$

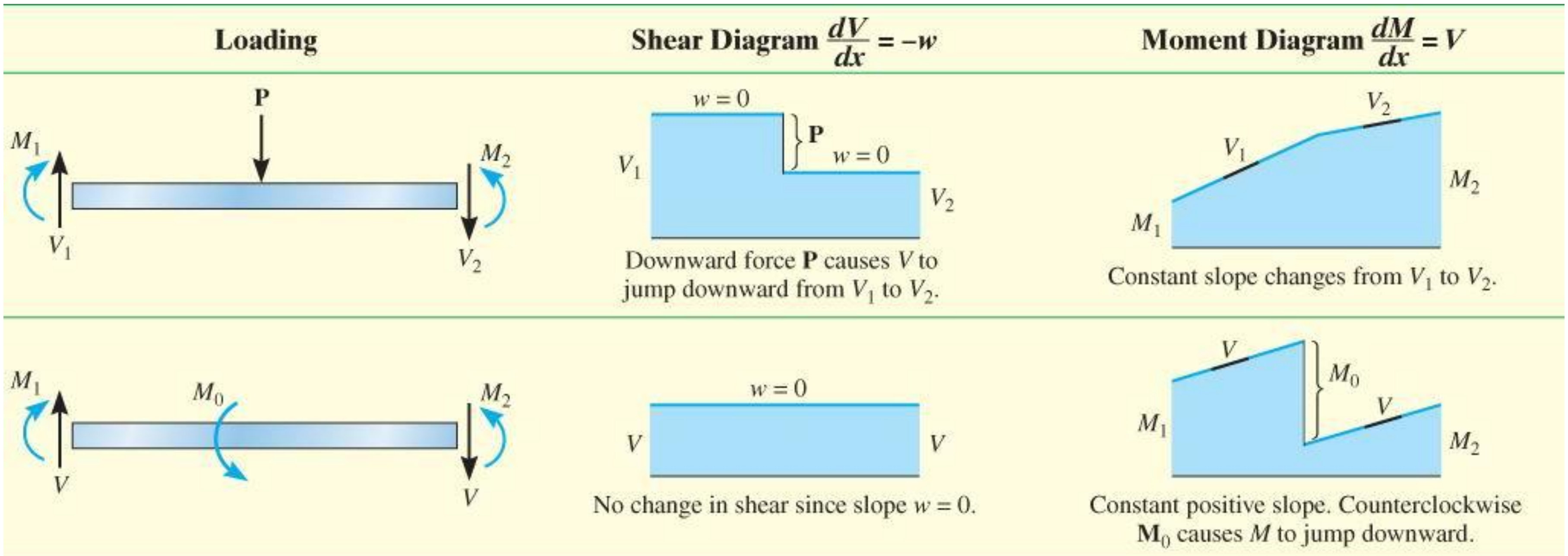
Change in shear = –area under distributed loading

$$\Delta M = \int V(x)\, dx$$

Change in moment = area under shear

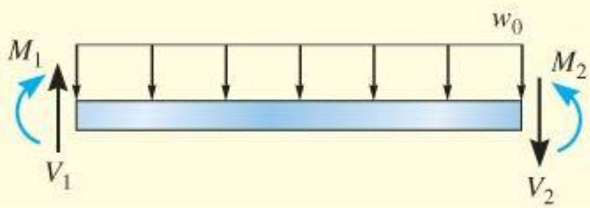
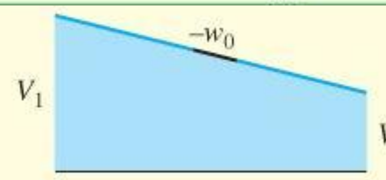
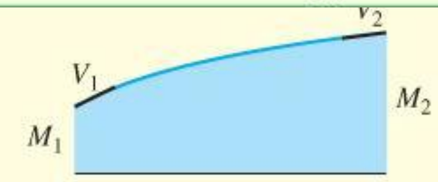
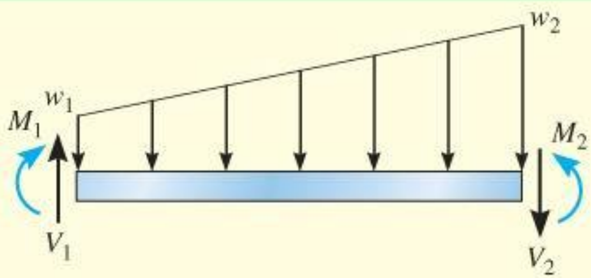
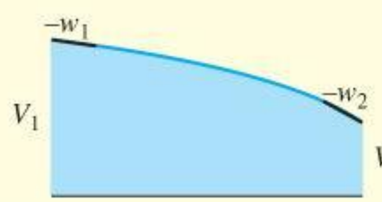
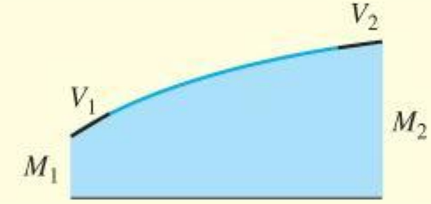
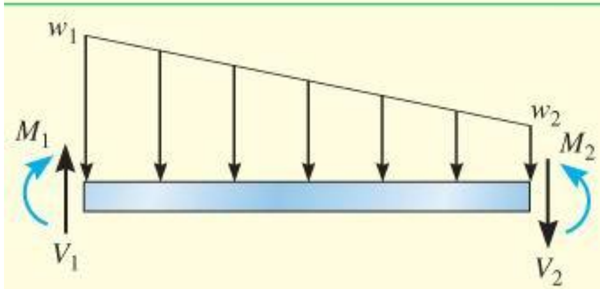
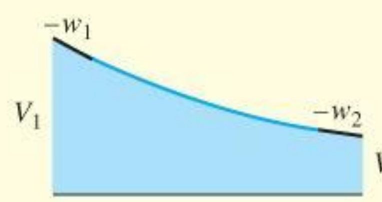
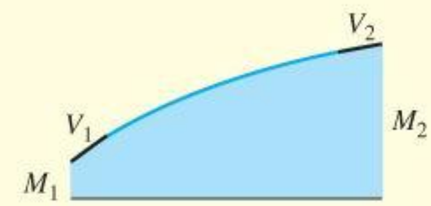
Graphical Method for Constructing Shear and Moment Diagrams

Regions of concentrated force and moment



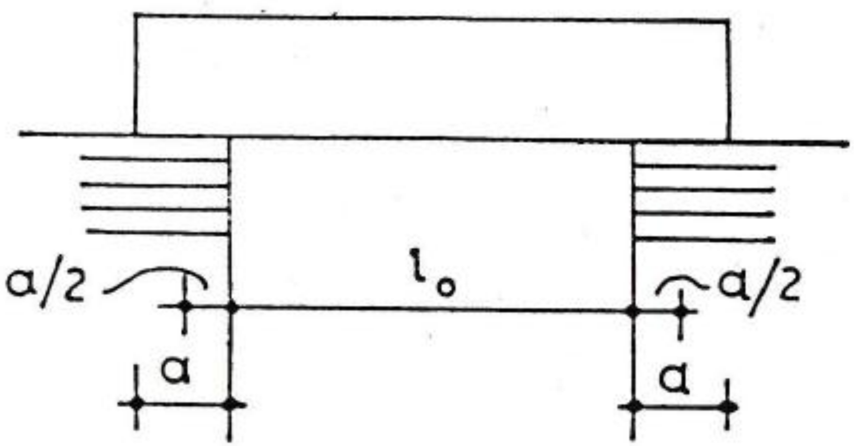
Graphical Method for Constructing Shear and Moment Diagrams

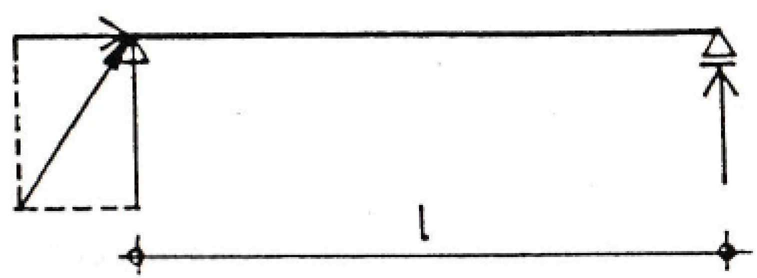
Regions of distributed force

Loading	Shear Diagram $\frac{dV}{dx} = -w$	Moment Diagram $\frac{dM}{dx} = V$
	 Constant negative slope.	 Positive slope that decreases from V_1 to V_2.
	 Negative slope that increases from $-w_1$ to $-w_2$.	 Positive slope that decreases from V_1 to V_2.
	 Negative slope that decreases from $-w_1$ to $-w_2$.	 Positive slope that decreases from V_1 to V_2.

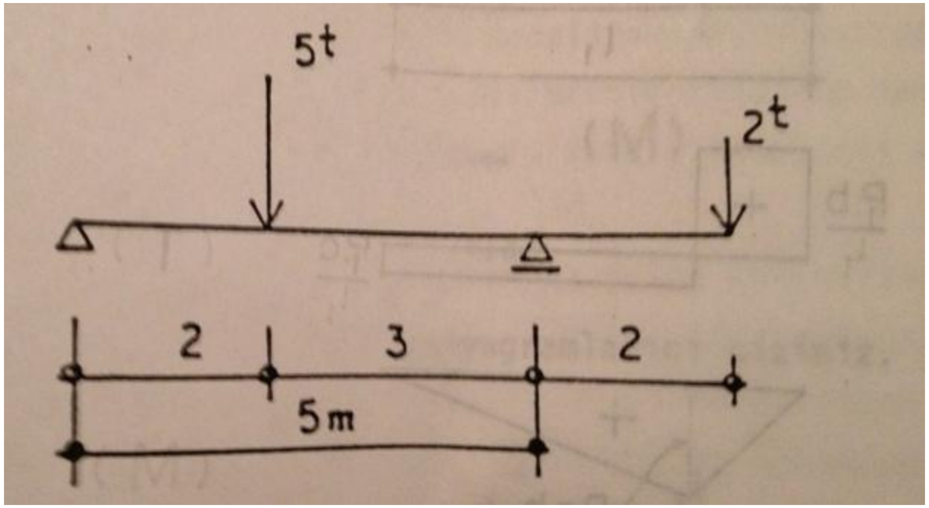
ANALYSIS OF STATICALLY DETERMINATE STRUCTURES

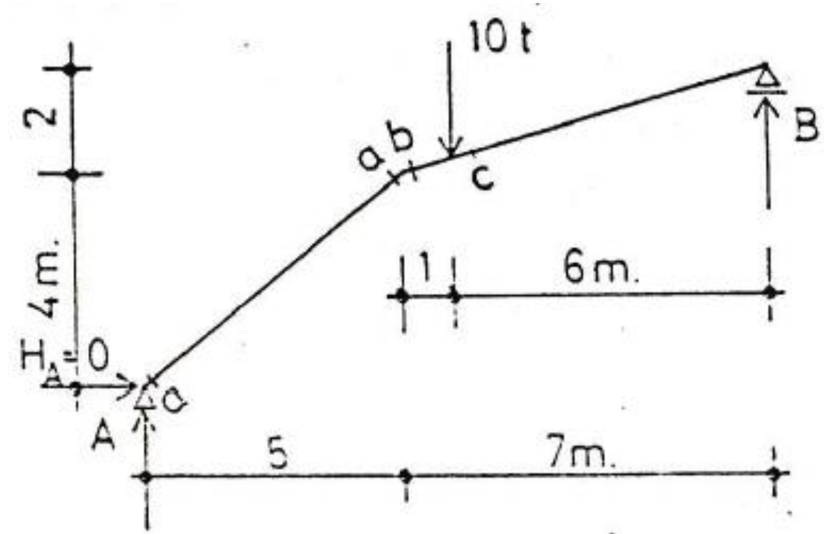
Simply Supported Beams



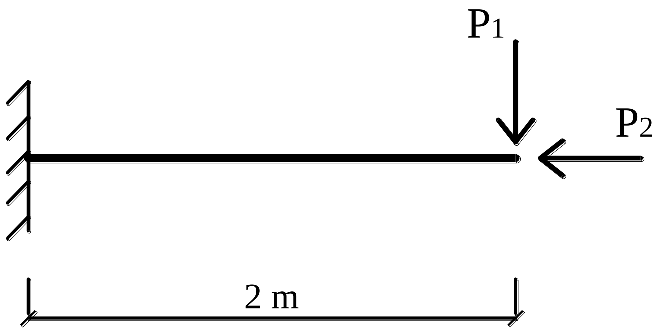


Statically Determinate Beams

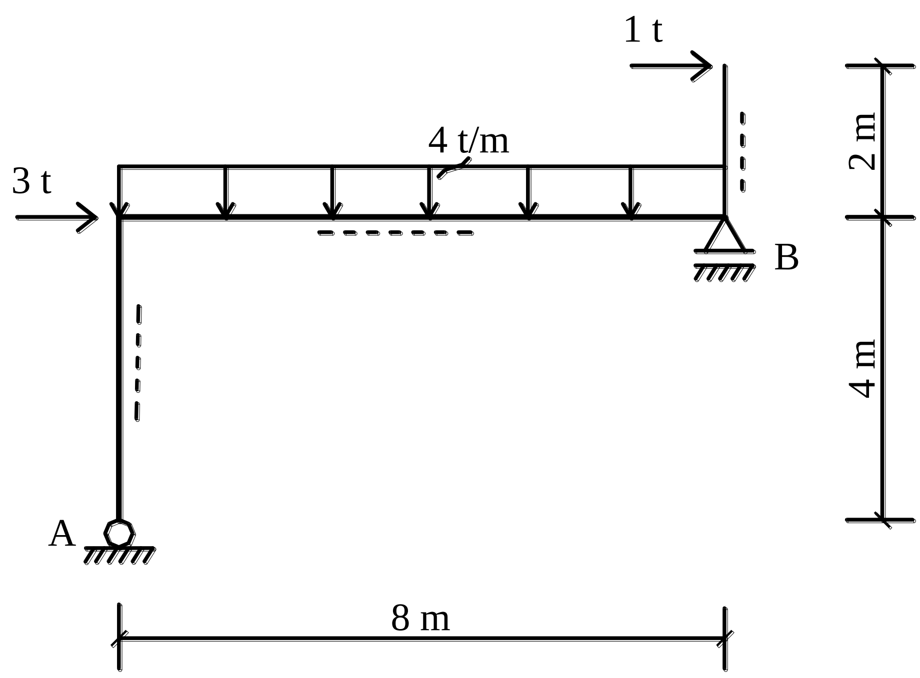


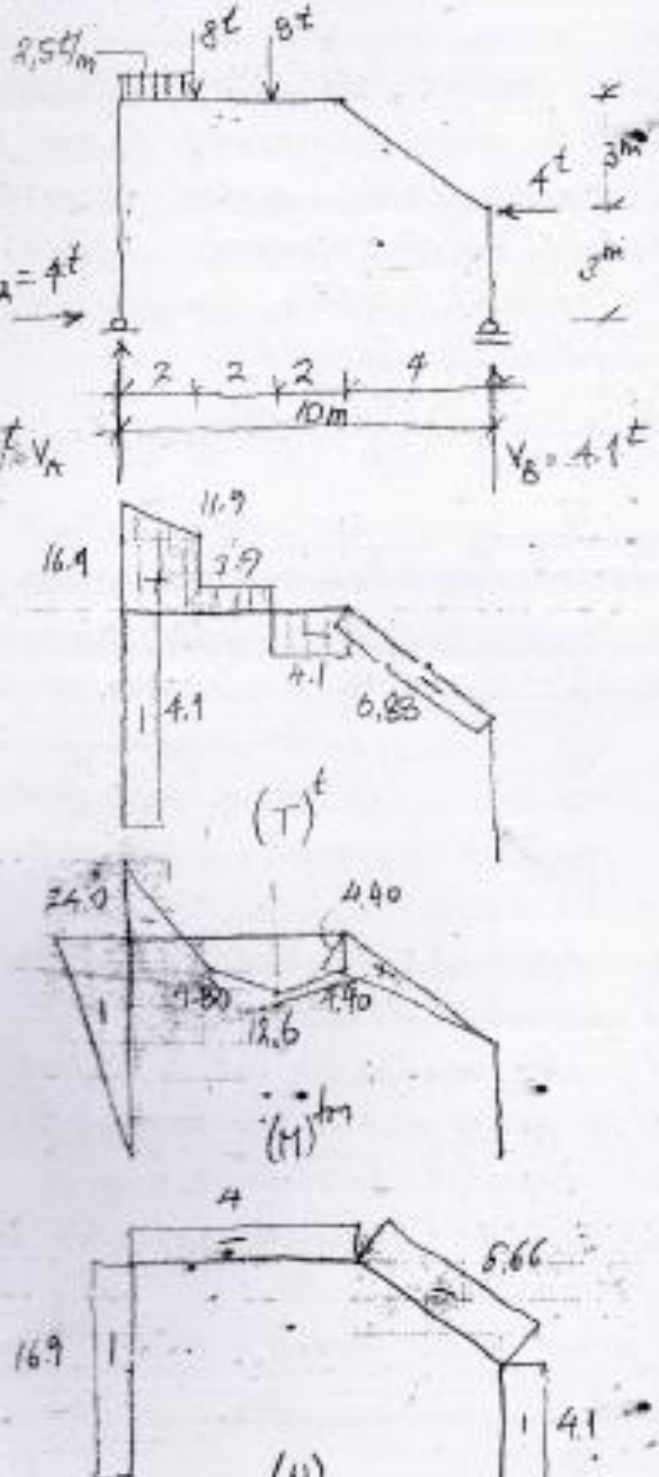


Cantilever Beams



Statically Determinate Frames



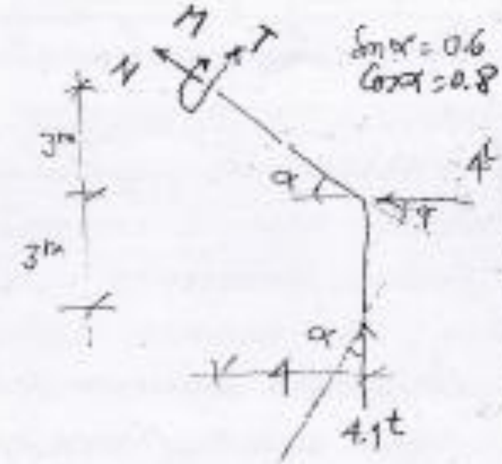


$\Sigma X = 0 \quad H_A = 4^t$

$\Sigma Y = 0 \quad V_A + V_B - (2)(2,5) - (2)(8) = 0$

$\Sigma M_A = 0 \quad (V_B)(10) + (4)(3) - (8)(4) - (8)(2) - (5)(1) = 0$

$V_B = 4.1^t \qquad V_A = 16,9^t$



$\Sigma N = 0 \quad N + (4)(\cos\alpha) + (4.1)(\sin\alpha) = 0$

$N = -5.66^t$

$\Sigma T = 0 \quad T - (4)\sin\alpha + (4.1)\cos\alpha = 0$

$T = -0.88^t$

$\Sigma M = 0 \quad M + (4)(3) - (4.1)(4) = 0$

$M = 4.4\ t_m$

REFERENCES

Hibbeler, R.C. `Structural Analysis`, Prentice Hall.

Yorulmaz, M., Özgen, K. `Yapı Statiği`, Birsen Yayınevi

Lecture Notes by Associate Prof.Dr. Serdar Soyöz

TS498- Yapı Elemanlarının Boyutlandırılmasında Alınacak Yüklerin Hesap Değerleri - Design Loads For Buildings