Mechanics of Materials

(http://bernoulli.iam.ntu.edu.tw/)

***By Prof. Dr.-Ing. An-Bang Wang*（王安邦）**

Chapter 1

INTRODUCTION AND REVIEW OF STATICS*

(* Statics is concerned with bodies that are acted on by *balanced forces*)

Preface (I)

- **Grading Policy: Homework 15%, Mid-term exam 25+25%, Final exam 25%, Quizzes 10% + Q&A 10%**
- 課程要求： 課堂講解+實做，有平時表現(+IRS)、習題作業、學期作業、期中考與期末考。 作弊該次行為不計分，且考試作弊一律送學校處理。
- ***Textbook*： W. F. Riley, L. D. Sturges, and D. H. Morris, Mechanics of Materials, 6th Ed., John Wiley & Sons, 2007**
  ***Reference*： J. M. Gere (and S. T. Timoshenko), Mechanics of Materials, 6th Ed., Thomson Brooks/Cole, 2004.**
- 先修科目: 普通物理學甲上
- 作業要求：
  1.作業指定後再隔週上課前繳交至講桌上，作業遲交扣分。
  2.作業若有抄襲情事，被抄與抄襲者該次作業不計分。
- 授課老師： 王安邦 (應力館405室) ，02-33665651 ，
  e-mail: abwang@spring.iam.ntu.edu.tw
- **Office Hours： 每週二 12:20~13:10 @ R405 (IAM)**
- 助　　教：甘名揚 (舊數學館303) ，
  電話: 33663069，行動電話 : 0987202489，
  e-mail: r05524021@ntu.edu.tw

Preface (II)

- 課程概述： 本課程介紹材料力學的基本概念與分析方法，以瞭解基本構件受力後的應力與應變狀況。
- 課程目標： 課程結束時，修課同學應具備以下能力：
  1.了解應力的定義，能推導不同方向應力的轉換公式，並能計算主應力及最大剪應力。
  2.能以位移、變形及應變來描述物體形狀的變化，了解應變在不同方向的轉換公式，並能計算主應變及最大剪應變。
  3.了解材料之材料特性及其應力–應變關係。
  4.了解材料強度及安全係數的觀念。
  5.能分析桿件受軸向荷重的應力及變形。
  6.能分析壓力容器的應力分佈。
  7.了解應力集中現象。
  8.能分析桿件兩端受扭力作用的應力及變形。
  9.能分析梁受彎矩或側向力作用的應力及變形。

課程大綱
& Schedule of Teaching Plan

1. **Introduction and Review of Statics 9/12, 9/15**
2. **Analysis of Stress: Concepts and Definitions 9/19, 9/22, 9/26, 9/29, 10/03, 10/6,10/13, 10/17**
3. **Analysis of Strain: Concepts and Definitions 10/17, 10/20, 10/24**
4. **Material Properties and Stress-Strain Relationships 10/24, 10/27, (10/31), 11/03, 11/07, 11/10**
5. **Axial Loading Applications and Pressure Vessels 11/14, 11/17, 11/21, 11/24**
6. **Torsional Loading of Shafts 11/24, 11/28, 12/01, 12/08, 12/12, 12/15,**
7. **Flexural Loading: Stresses in Beams 12/15, 12/19, 12/22, 12/26, 12/29,**
8. **Flexural Loading: Beam Deflections 12/29, 01/02, 01/05**

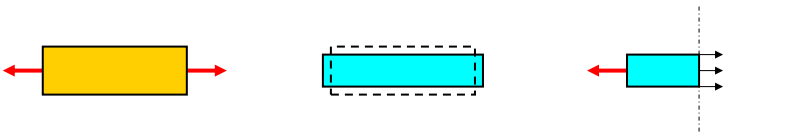
- **Expected 1st Midterm exam: 2017/10/31 (Tue)**
- **Expected 2nd Midterm exam:2017/12/05 (Tue)**
- **Semester homework: 2017/12/08 (Fri)**
- **Final exam: 2017/01/09 (Tue)**

1-1 Introduction

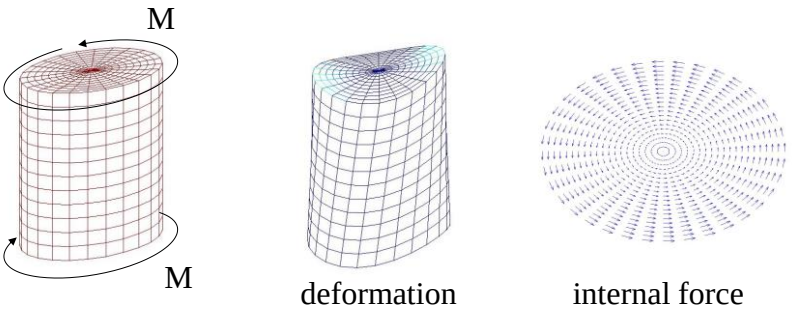
- Objective

  Development of relationships between the loads applied to a ***nonrigid*** body and the internal forces and deformations induced in the body.

Example



deformation internal force



deformation internal force

1-2 Classification of Forces

- contact ~ noncontact
  (surface) (weight)
- concentrated ~ distributed
- external ~ internal (see 1-5 in detail)
- applied ~ reactions
- static ~ dynamic (impact, cyclic…)

Concentrated Load ~ Distributed Load

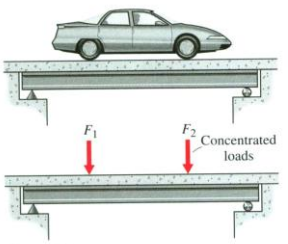
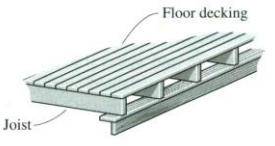
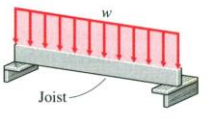


Figure 1-1

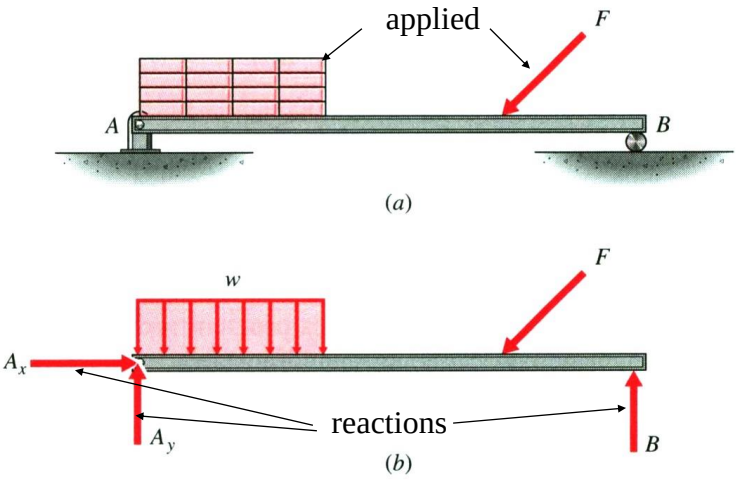


igure 1-2



concentrated distributed

Types of Loads



1-3 Equilibrium of a Rigid Body (I)

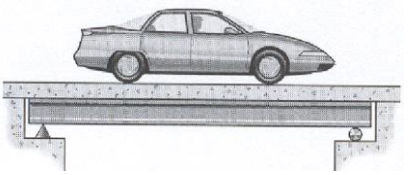
Rigid body: a body that does not deform under the action of applied loads

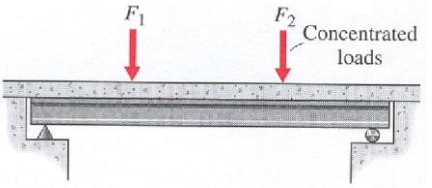
$$\begin{cases} \sum \mathbf{F} = \mathbf{0} \\ \sum \mathbf{M_O} = \mathbf{0} \end{cases}$$

$$\begin{cases} \sum F_x = 0 & \sum F_y = 0 & \sum F_z = 0 \\ \sum M_x = 0 & \sum M_y = 0 & \sum M_z = 0 \end{cases}$$

1-3 Equilibrium of a Rigid Body (II)

Free-body diagram (FBD) **:**
A (carefully prepared) drawing or sketch that shows a "*body of interest*" separated from all interacting bodies.





A review of Mechanics

Mechanics of rigid body
- **Statics**
- **Dynamics**
  - kinematics
  - kinetics

Mechanics of deformable body:
Mechanics of Materials

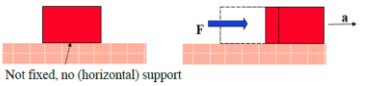
Elasticity
Plasticity
Rheology

Mechanics of fluid (continuous deforming)

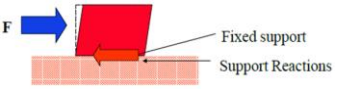
(review)

A review of Mechanics: Forces

- A ***force*** is described by its magnitude, direction, and point of application. Force is a **vector** quantity.
- Effects of a force on a body:



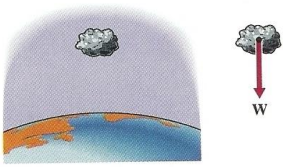
  - external effect: change body motion (dynamic), or develop reactions on the body (static).
  - internal effect: deform the body → stress/strain (mechanics of materials).



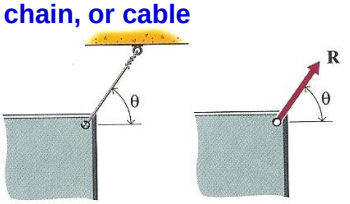
(review)

A review of Mechanics: 2-D Reactions at Supports and Connections (Table 6-1 & 6-2 in **Statics**, Riley & Sturges)

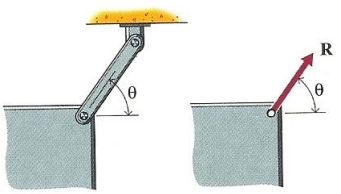
1. Gravitational attraction



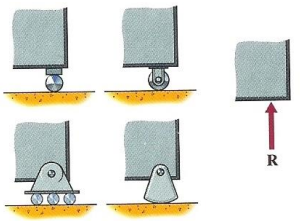
2. Flexible cord, rope, chain, or cable



3. Rigid link



4. Ball, roller, or rocker

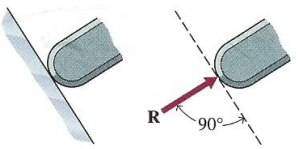


(review)

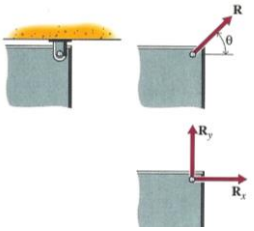
Link bar: two-force member

A review of Mechanics: 2-D Reactions at Supports and Connections

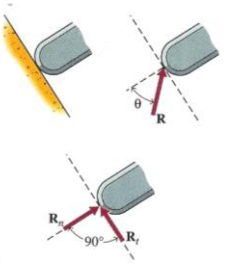
5. Smooth surface



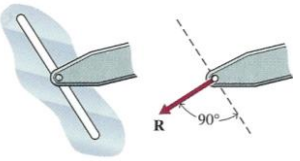
6. Smooth pin



7. Rough surface



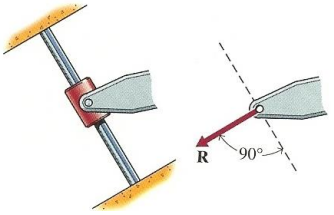
8. Pin in a smooth guide

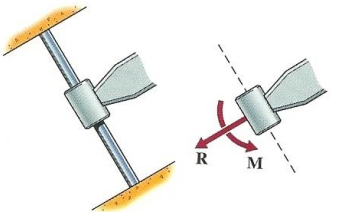


(review)

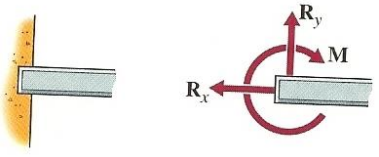
A review of Mechanics: 2-D Reactions at Supports and Connections

9. Collar on a smooth shaft

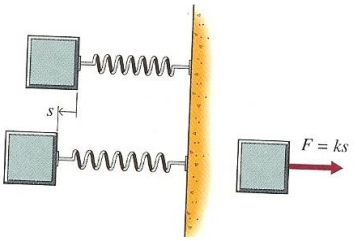




10. Fixed support



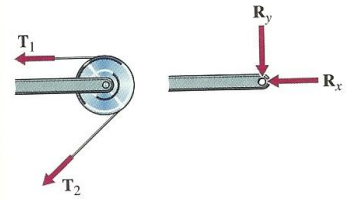
11. Linear elastic spring



(review)

A review of Mechanics: 2-D Reactions at Supports and Connections

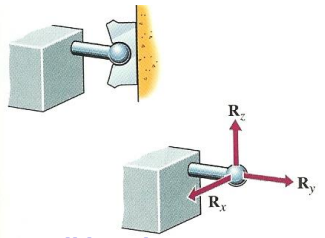
12. Ideal pulley



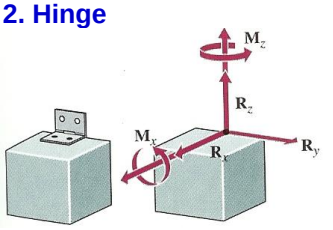
(review)

A review of Mechanics: 3-D Reactions at Supports and Connections

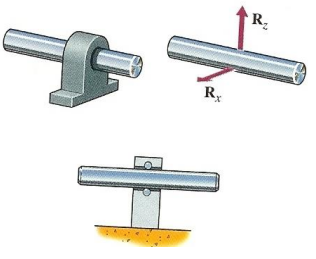
1. Ball and socket



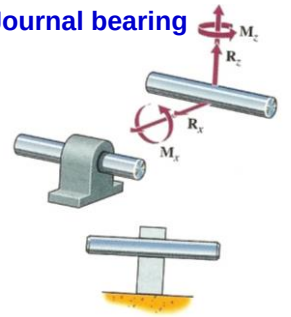
2. Hinge



3. Ball bearing



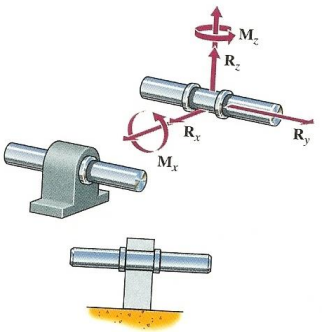
4. Journal bearing



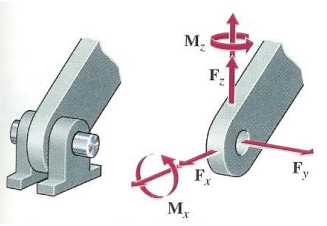
(review)

A review of Mechanics: 3-D Reactions at Supports and Connections

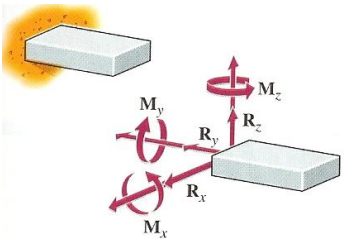
5. Thrust bearing



6. Smooth pin bracket

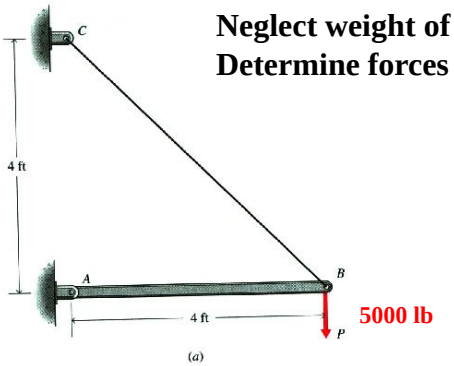


7. Fixed support



(review)

Example Problem 1-1

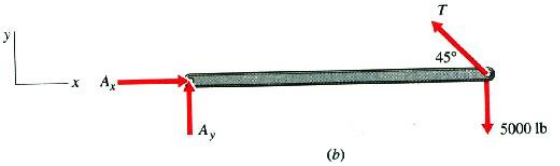


Neglect weight of members
Determine forces at A=? & Tension =?

$$\sum M_A = 0 \Rightarrow T$$

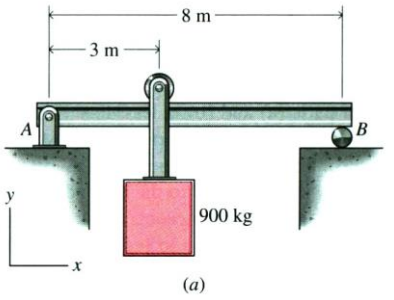
$$\sum F_x = 0 \Rightarrow A_x$$

$$\sum F_y = 0 \Rightarrow A_y$$



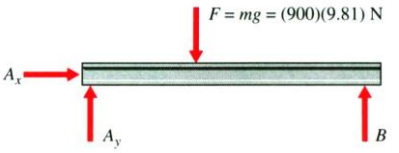
Free-body diagram

Example Problem 1-2



Neglect Beam mass
Determine reactions A=? & B=?

(a) Neglect beam weight

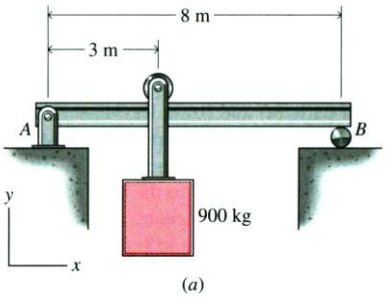


$$\sum M_A = 0 \Rightarrow B$$

$$\sum F_x = 0 \Rightarrow A_x$$

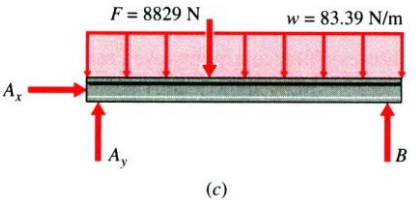
$$\sum F_y = 0 \Rightarrow A_y$$

Example Problem 1-2



Beam mass = 8.5 kg/m
Determine reactions A=? & B=?

(b) Include beam weight



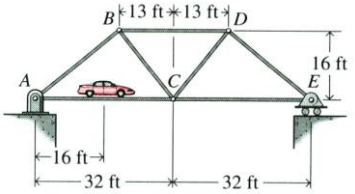
$$\sum M_A = 0 \Rightarrow B$$

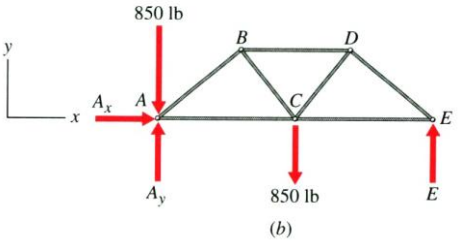
$$\sum F_x = 0 \Rightarrow A_x$$

$$\sum F_y = 0 \Rightarrow A_y$$

Example Problem 1-3

(consider one side)





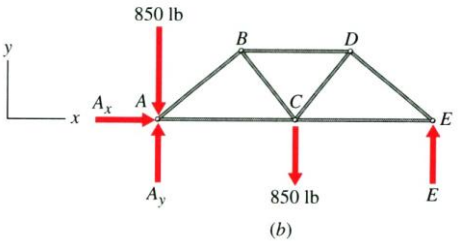
Car = 3400 lb
Determine forces in members
BD=? DE=? & CE=?

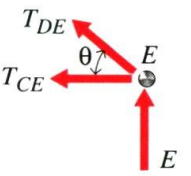
$$\sum M_A = 0 \Rightarrow E$$

$$\sum F_x = 0 \Rightarrow A_x$$

$$\sum F_y = 0 \Rightarrow A_y$$

Example Problem 1-3 (continued)

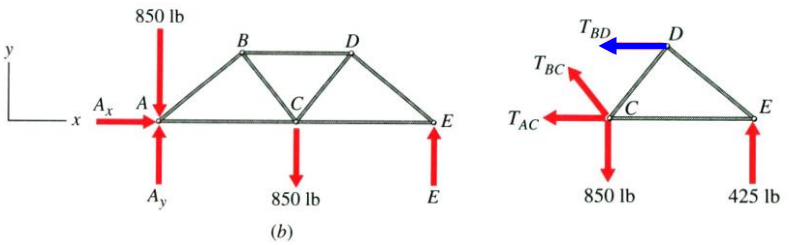




Method of joints

$$\begin{cases} \sum F_x = 0 \\ \sum F_y = 0 \end{cases} \Rightarrow \begin{cases} T_{CE} \\ T_{DE} \end{cases}$$

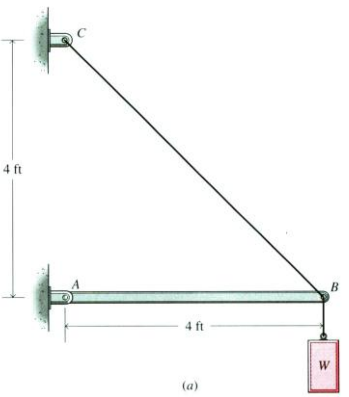
Example Problem 1-3 (continued)



Method of Sections $\sum M_C = 0$ ⇨ T_{BD}

1-4 Equilibrium of a Deformable Body

- Example Problem 1-8



Assumptions:

bar *AB* rigid

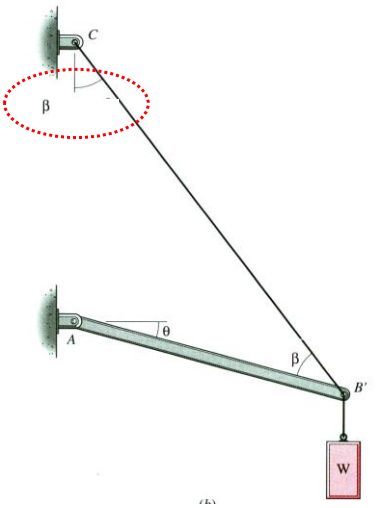
wire *BC* deformable

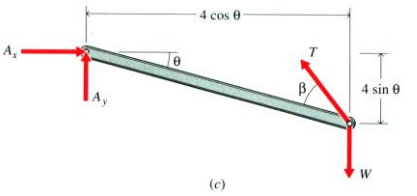
pins frictionless

$T_{BC} = k\delta$, k = 2500 lb/in

Determine tension in wire=?

Example Problem 1-5





3 equil. eqs 4 unknowns

$\sum M_A = 0$ A_x

$\sum F_x = 0$ A_y

T

$\sum F_y = 0$ θ

\+ $T_{BC} = k\delta$ **force-deformation**

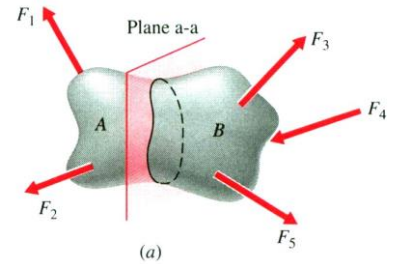
Influence of Wire Elongation

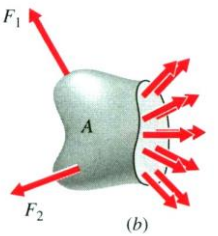
	rigid wire	k = 5000 lb/in	k = 2500 lb/in	k = 2000 lb/in
T	7071 lb	7221 lb	7379 lb	7893 lb
θ	0°	2.465°	5.097°	14.246°

Solution of Defomable Body Problems

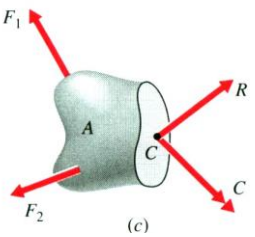
- Equations of equilibrium
- Force-deformation relationship
- Geometry of deformation

1-5 Internal Forces

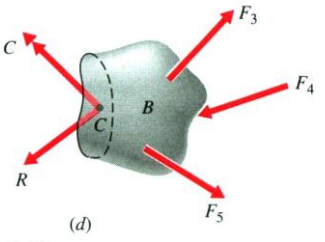




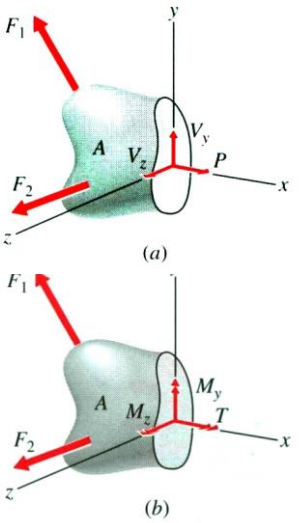
internal forces



resultant force and couple



Resultant Force and Couple



$\mathbf{R} \Rightarrow P, V_y, V_z$

P : normal force

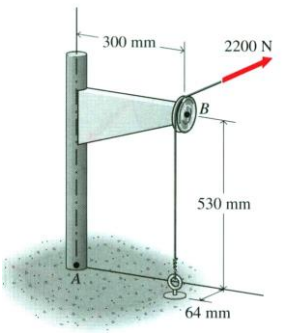
V_y , V_z: shear forces

$\mathbf{C} \Rightarrow T, M_y, M_z$

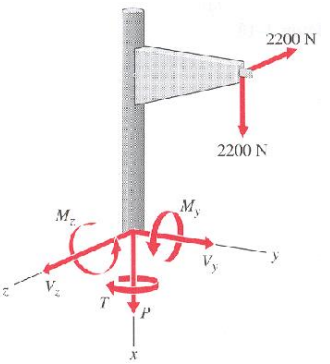
T : twisting moment or torque

M_y , M_z: bending moments

Example Problem 1-9



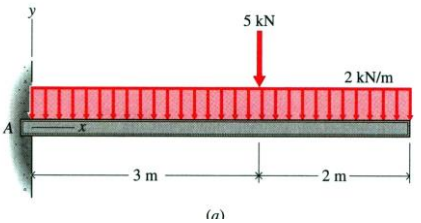
$$\sum F_x = 0 \qquad \sum M_x = 0$$
$$\sum F_y = 0 \qquad \sum M_y = 0$$
$$\sum F_z = 0 \qquad \sum M_z = 0$$



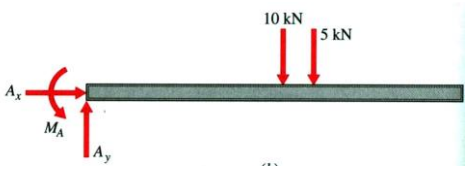
P, V_y, V_z

T, M_y, M_z

Example Problem 1-10

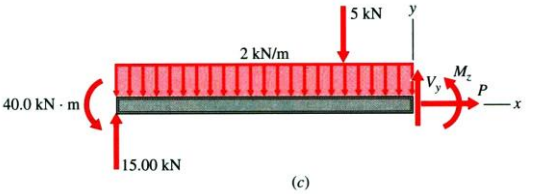


Determine (a) support reaction?
(b) internal force at x=4m?

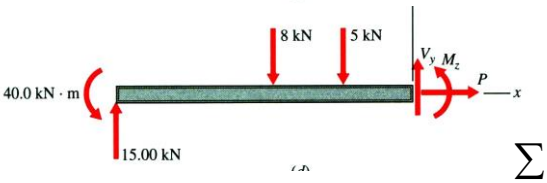


$$\sum M_A = 0 \Rightarrow M_A = ?$$
$$\sum F_x = 0 \Rightarrow A_x = ?$$
$$\sum F_y = 0 \Rightarrow A_y = ?$$

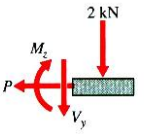
Example Problem 1-10



(c)



or



$$\sum M_Z = 0 \Rightarrow M_z$$
$$\sum F_x = 0 \Rightarrow P$$
$$\sum F_y = 0 \Rightarrow V_y$$

6 Exercises

1-9, 1-21, 1-25, 1-63, 1-76, 1-83