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)

- 課程要求： 以課堂講解為主，有習題作業、平時表現、期中考與期末考。考試作弊該次考試不計分，且一律送學校處理。
- 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。
- 先修科目:普通物理學甲上
- **Grading Policy: Homework 15%, Mid-term exam 25+25%, Final exam 25%, Quizzes 10% + Q&A 5%**
- **Office Hours**： 每週五 **10:00~11:00 @ R405 (IAM)**
- ***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.**
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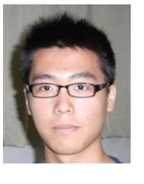
  e-mail: abwang@spring.iam.ntu.edu.tw
- 助　　教：李孟憲(工綜館**420** 室) ，
  電話:**33663061**，行動電話 : **0911693763**，
  e-mail: r02524005@ntu.edu.tw



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 9/16, 9/19, 9/23**
2. **Analysis of Stress: Concepts and Definitions 9/23, 9/26, 9/30,10/03, 10/7**
3. **Analysis of Strain: Concepts and Definitions 10/07,10/14, 10/17,**
4. **Material Properties and Stress-Strain Relationships 10/17, (10/21), 10/24, 10/28, 10/31**
5. **Axial Loading Applications and Pressure Vessels 11/04, 11/07, 11/11, 11/14, 11/18, 11/21**
6. **Torsional Loading of Shafts 11/25, 11/28, (12/02), 12/05, 12/09,**
7. **Flexural Loading: Stresses in Beams 12/09, 12/12, 12/16, 12/19, 12/23,**
8. **Flexural Loading: Beam Deflections 12/26, 12/30, 01/02**

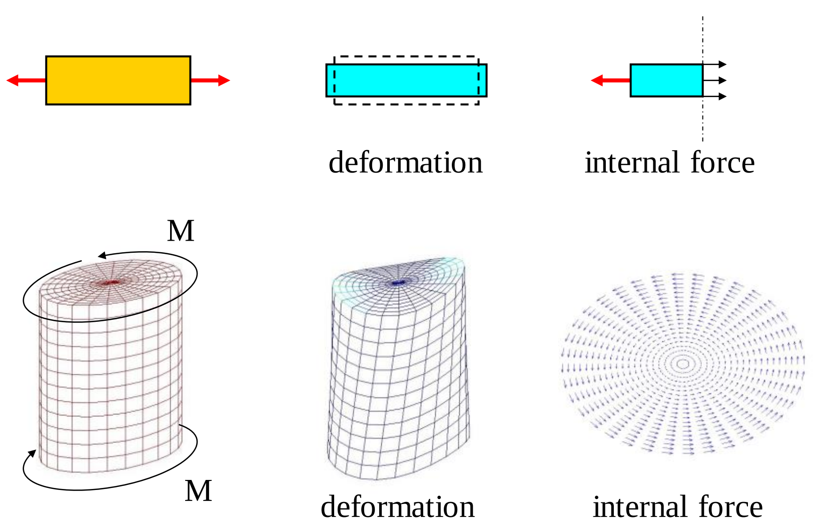
- **Expected 1st Midterm exam: 2014/10/21**
- **Expected 2nd Midterm exam:2014/12/02**
- **Final exam: 2015/01/13**

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



1-2 Classification of Forces

- contact ~ noncontact

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

1-3 Equilibrium of a Rigid Body (I)

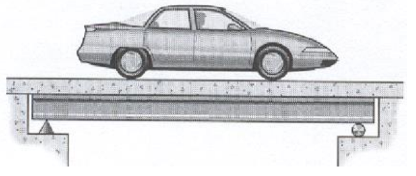
Rigid body: a body that does not deform under the action of applied loads

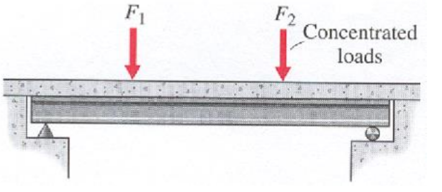
$$\begin{cases} \sum \mathbf{F} = \mathbf{0} \\ \sum \mathbf{M}_O = \mathbf{0} \end{cases}$$

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

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

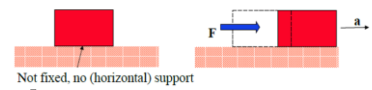
Elasticity
Plasticity
Rheology

Mechanics of fluid (continuous deforming)

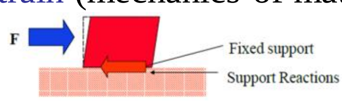
(review)

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:



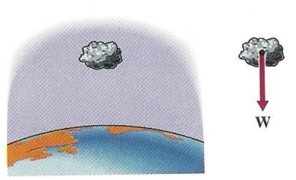
  - external effect: change body motion (dynamic), or develop reactions on the body (static).
  - internal effect: deform the body → stress/strain (mechanics of materials).



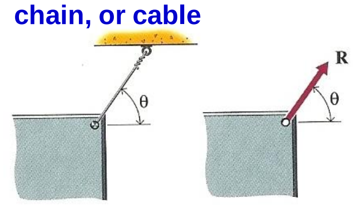
(review)

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

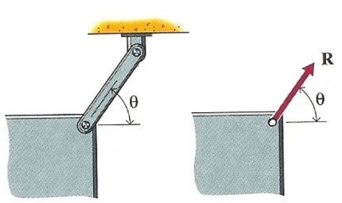
1. Gravitational attraction



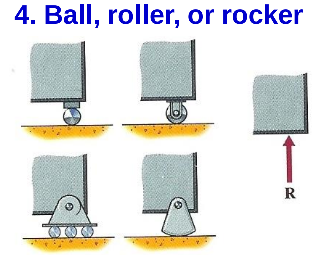
2. Flexible cord, rope, chain, or cable



3. Rigid link



4. Ball, roller, or rocker

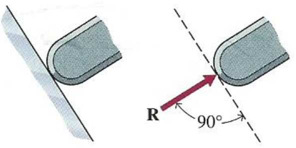


(review)

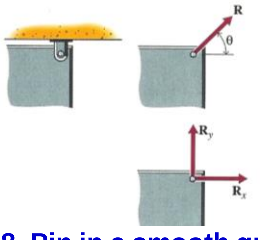
Link bar: two-force member

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

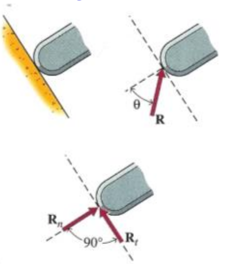
5. Smooth surface



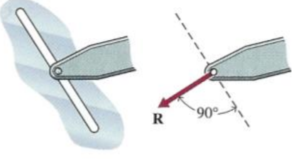
6. Smooth pin



7. Rough surface



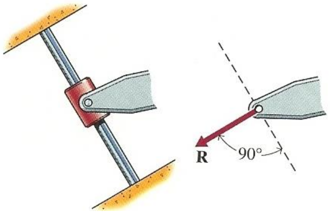
8. Pin in a smooth guide

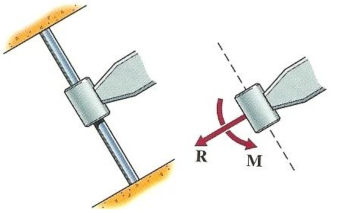


(review)

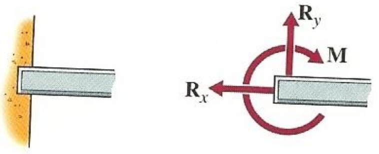
A review of Mechanics: 2-D Reactions at Supports and Connections

9. Collar on a smooth shaft

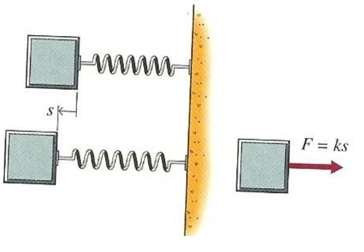




10. Fixed support



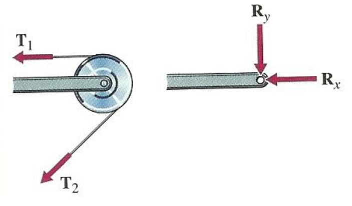
11. Linear elastic spring



(review)

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

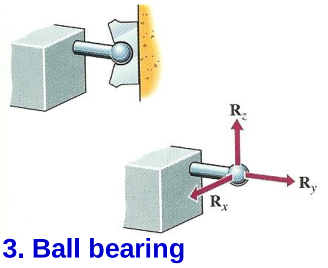
12. Ideal pulley



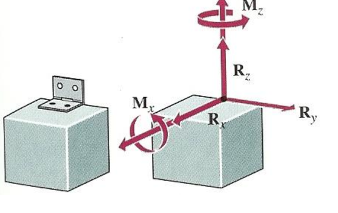
(review)

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

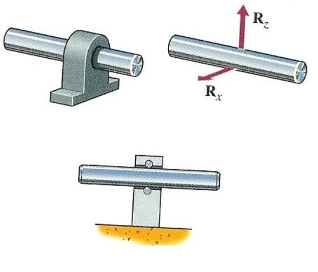
1. Ball and socket



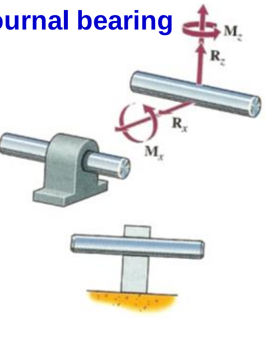
2. Hinge



3. Ball bearing



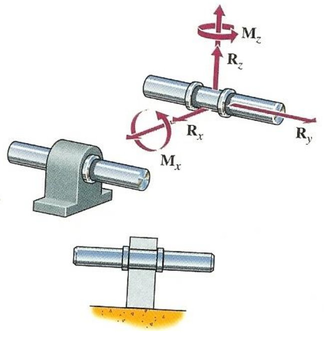
4. Journal bearing



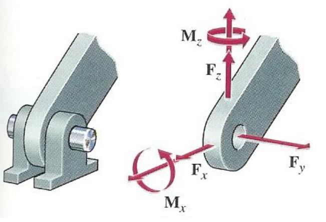
(review)

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

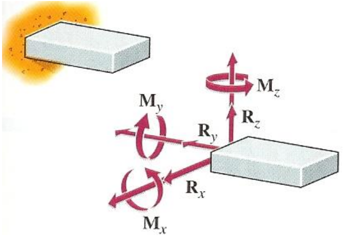
5. Thrust bearing



6. Smooth pin bracket



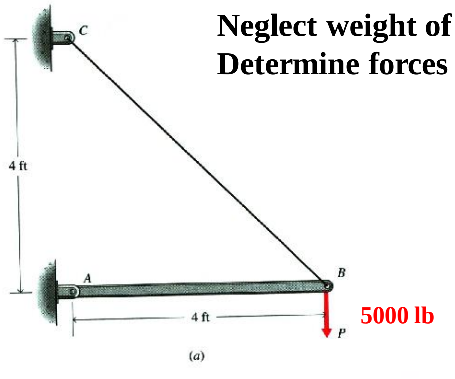
7. Fixed support



(review)

Example Problem 1-1

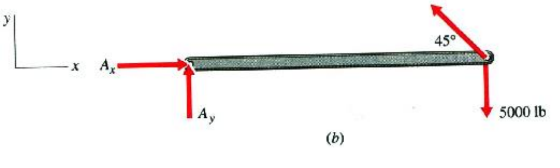
Neglect weight of members
Determine forces at A=? & Tension =?



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

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

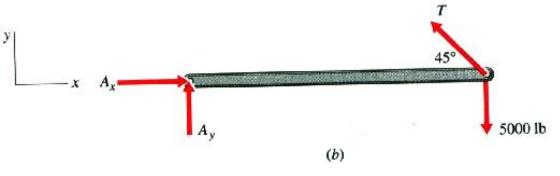
$$\sum F_y = 0 \Rightarrow A_y$$



Free-body diagram

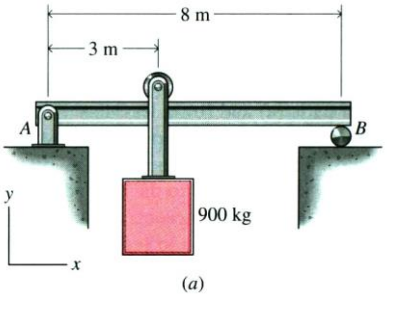
Which one is correct?

- 1. T = 5000 lb
- 2. T = 7071 lb
- 3. T = 0 lb
- 4. T = 2500 lb
- 5. 以上皆非

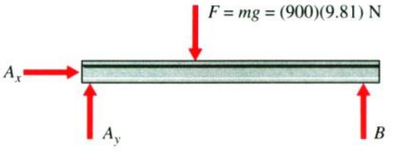


Free-body diagram

Example Problem 1-2



(a) Neglect beam weight



$\sum M_A = 0 \Rightarrow B$

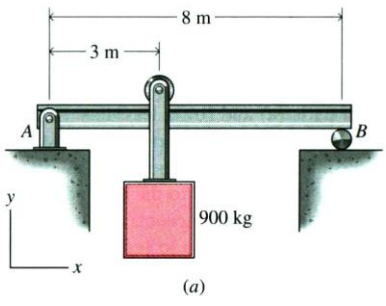
$\sum F_x = 0 \Rightarrow A_x$

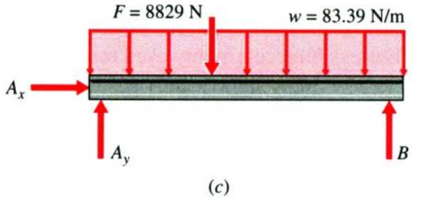
$\sum F_y = 0 \Rightarrow A_y$

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

Example Problem 1-2

(b) Include beam weight





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

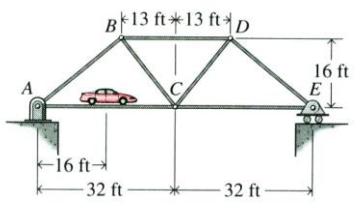
$\sum M_A = 0$ ⇨ B

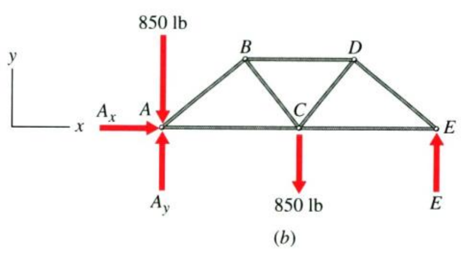
$\sum F_x = 0$ ⇨ A_x

$\sum F_y = 0$ ⇨ A_y

Example Problem 1-3

(consider one side)





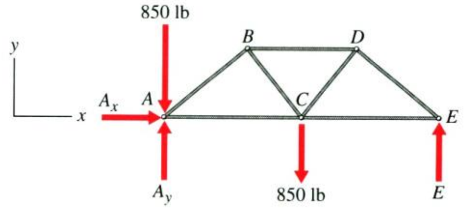
Car = 3400 lb
Determine forces in members
BD=? DE=? & CE=?

$\sum M_A = 0$ ⇨ E

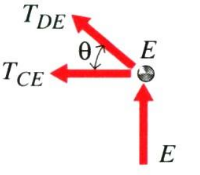
$\sum F_x = 0$ ⇨ A_x

$\sum F_y = 0$ ⇨ A_y

Example Problem 1-3 (continued)



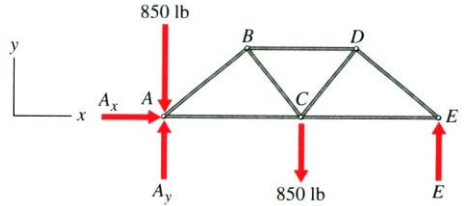
(b)



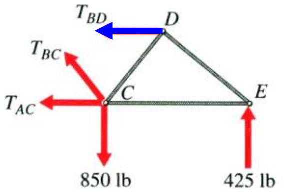
Method of joints

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

Example Problem 1-3 (continued)



(b)

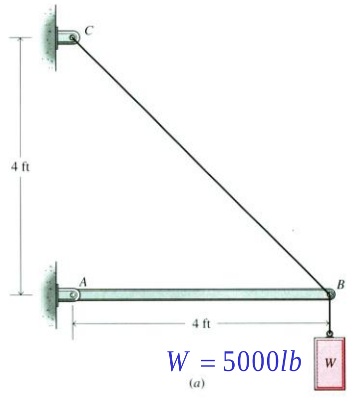


Method of Sections

$$\sum M_C = 0 \Rightarrow T_{BD}$$

1-4 Equilibrium of a Deformable Body

- Example Problem 1-8



Assumptions:

bar *AB* rigid

wire *BC* deformable

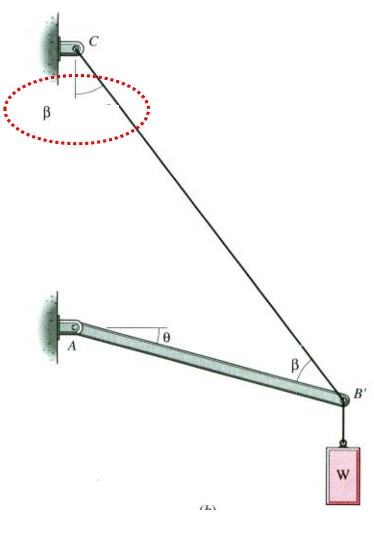
pins frictionless

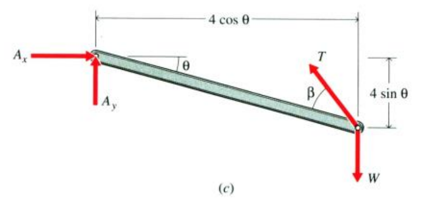
$T_{BC} = k\delta$, k = 2500 lb/in

$\delta = L_f - L_i$

Determine tension in wire=?

Example Problem 1-5





3 equil. eqs	4 unknowns
$\sum M_A = 0$	$\boldsymbol{A_x}$
$\sum F_x = 0$	$\boldsymbol{A_y}$
	$\boldsymbol{T}$
$\sum F_y = 0$	$\boldsymbol{\theta}$

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

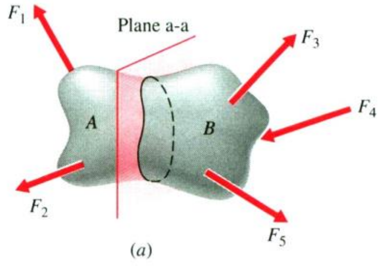
Influence of Wire Elongation

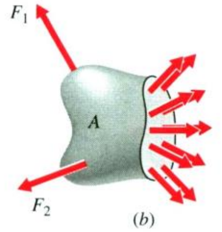
	rigid wire	*k* = 5000 lb/in	*k* = 2500 lb/in	*k* = 2000 lb/in
T	7071 lb	7221 lb	7379 lb	7893 lb
θ	0°	2.465°	5.097°	14.246°

Solution of Defomable Body Problems

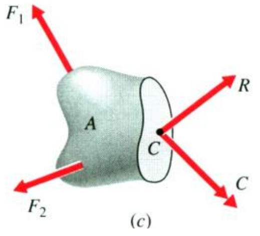
- Equations of equilibrium
- Force-deformation relationship
- Geometry of deformation

1-5 Internal Forces

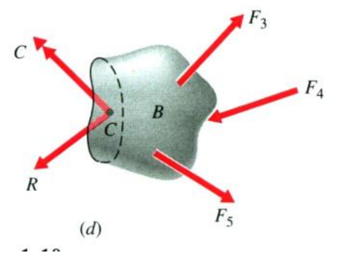




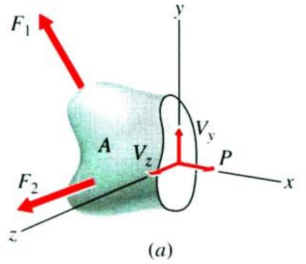
internal forces



resultant force and couple



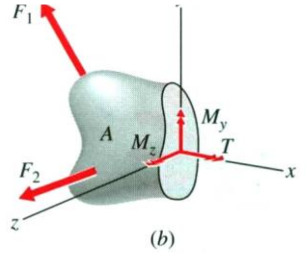
Resultant Force and Couple



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

P : normal force

V_y , V_z: shear forces

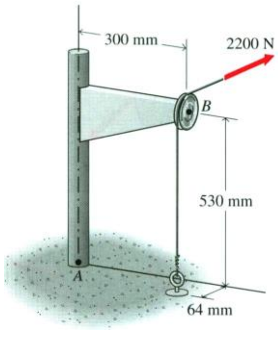


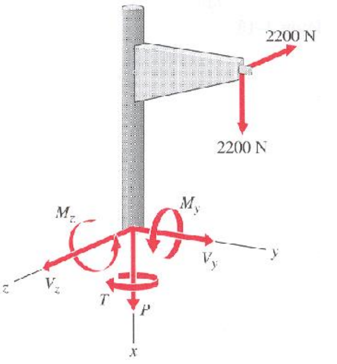
$\mathbf{C} \Rightarrow T, M_y, M_z$

T : twisting moment or torque

M_y , M_z: bending moments

Example Problem 1-9



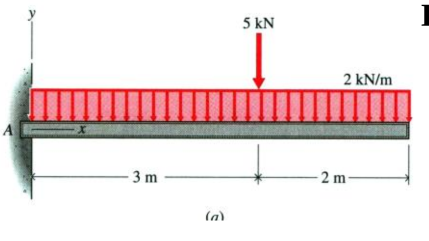


$$\sum F_x = 0 \quad \sum M_x = 0$$
$$\sum F_y = 0 \quad \sum M_y = 0$$
$$\sum F_z = 0 \quad \sum M_z = 0$$

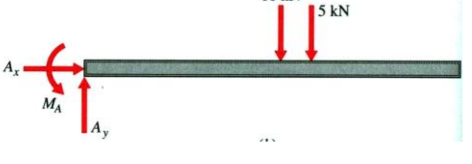
⇨ P, V_y, V_z

T, M_y, M_z

Example Problem 1-10



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



$\sum M_A = 0$ ⇨ $M_A = ?$

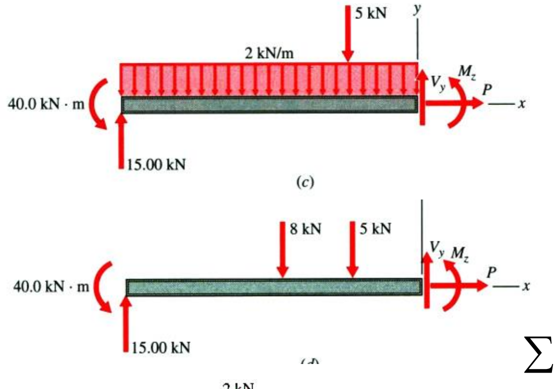
$\sum F_x = 0$ ⇨ $A_x = ?$

$\sum F_y = 0$ ⇨ $A_y = ?$

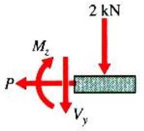
Which one is correct?

- 1 $M_A = 50\ kN.m\ \ A_x = 0\ kN,\ A_y = 15\ kN$
- 2 $M_A = 45\ kN.m\ \ A_x = 5kN,\ A_y = 15\ kN$
- 3 $M_A = 40\ kN.m\ \ A_x = 0\ kN,\ A_y = 15\ kN$
- 4 $M_A = 40\ kN.m\ \ A_x = 5\ kN,\ A_y = 15\ kN$
- **5. No correct answer**

Example Problem 1-10



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, 1-17, 1-25, 1-67, 1-77, 1-83

Concentrated Load ~ Distributed Load

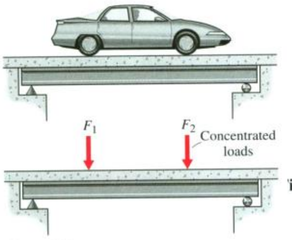
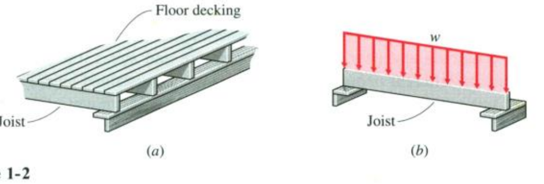


Figure 1-1



igure 1-2

concentrated distributed

Types of Loads