1. Essential Concepts

1.1 Introduction

- Mechanics
  - Classical -, Quantum -, Relativistic –, etc.
  - Statics: concerned with analysis of loads on physical systems in static equilibrium.
  - Dynamics: kinematics (운동학-시간과 속도, 가속도) and kinetics (운동역학 – 힘과 운동). Normally dealing with particles and rigid bodies.
  - Mechanics of materials: concerned with the behavior of solid materials such as bars, beams and columns on axial, torsional, and/or flexural loading.

- Primary objects of this course
  - Understanding relations between the load and deformation, load and stress, and stress and strain of a body
  - Familiar with fundamental concepts and skills for structural and machine design

1.2 Classification of forces

- Newton's three laws of Motion
  - The law of inertia: every object tends to remain in a state of motion without an external force on it.
  - F = ma: force equals mass times acceleration.
  - The law of action-reaction: To every action there is an equal and opposite reaction.

- Classification of forces
  - Contact force vs. body force: person standing on a sidewalk, electromagnetic, gravitation…
  - Concentrated force (load) vs. distributed force

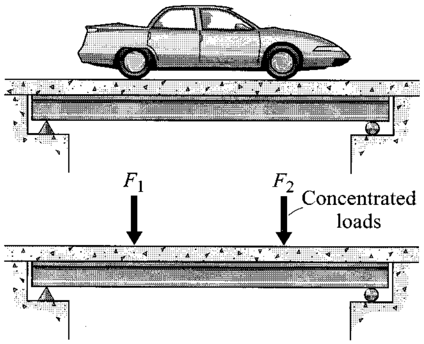


Figure 1-1

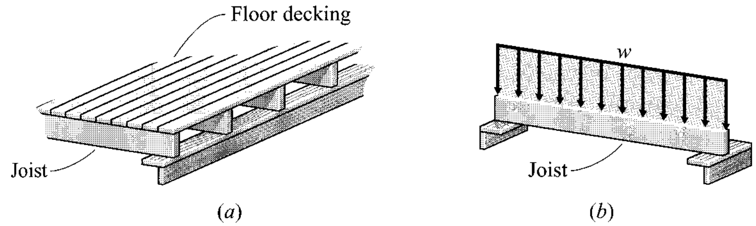


Figure 1-2

1.2 Classification of forces

- Applied force vs. reaction force

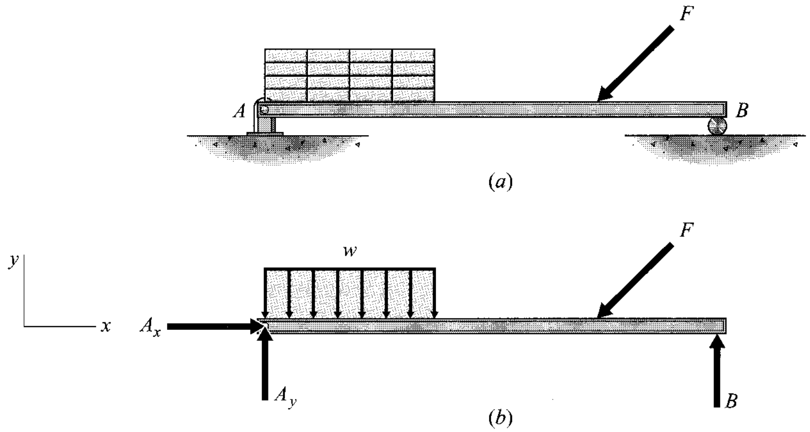


Figure 1-3

: Free-body diagram
(= a body of interest + ext. forces)

- External force vs. internal force: force on an object exerted by external sources
force at a section of an object

1.3 Equilibrium of a rigid body

- Equilibrium conditions (equations) of a rigid body

- $\sum F = 0 \left(\equiv \sum F_x = 0 , \sum F_y = 0 , \text{and} \sum F_z = 0\right)$
- $\sum M_0 = 0 \left(\equiv \sum M_x = 0 , \sum M_y = 0 , \text{and} \sum M_z = 0\right)$
- For 2D cases: $\sum F_x = 0 , \sum F_y = 0 , \text{and} \sum M_z = 0$
- For coplanar and concurrent cases: $\sum F_x = 0 , \sum F_y = 0$

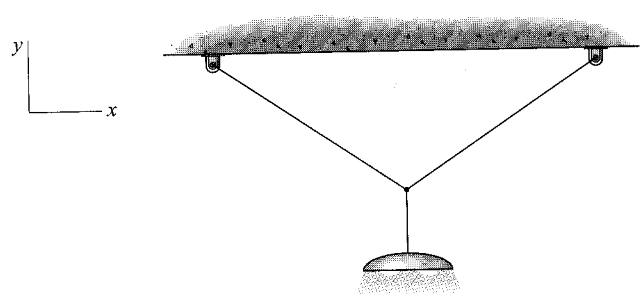


Figure 1-4

1.3 Equilibrium of a rigid body

- Example problem 1-1
  - Force at A and B

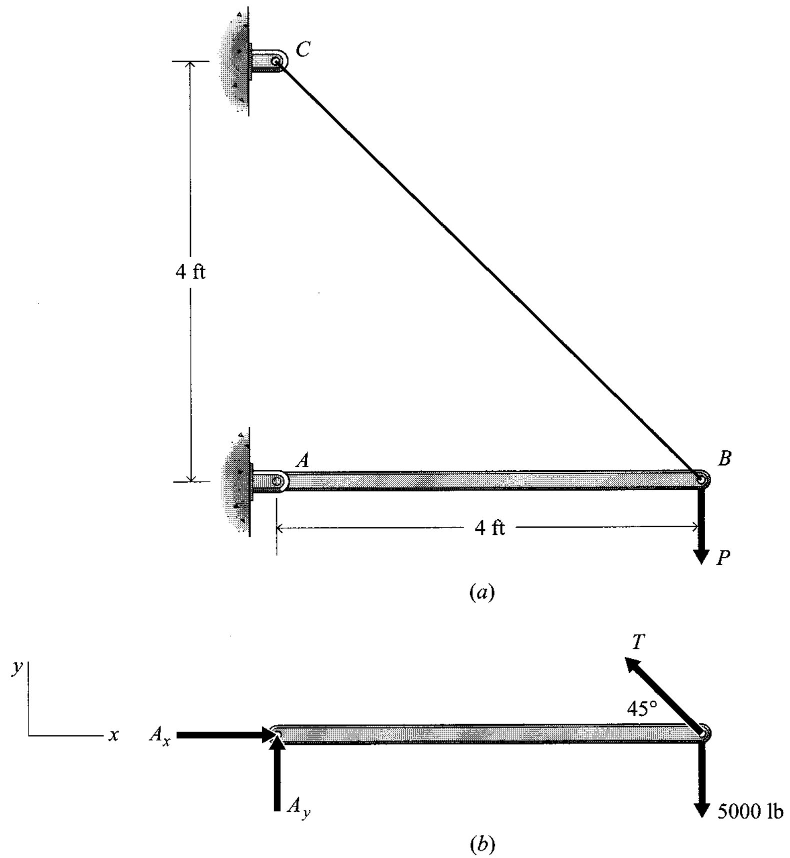


Figure 1-5

1.3 Equilibrium of a rigid body

- Example problem 1-2

- Force at A and B neglecting the beam mass

- Force at A and B at the beam mass of 8.5kg/m

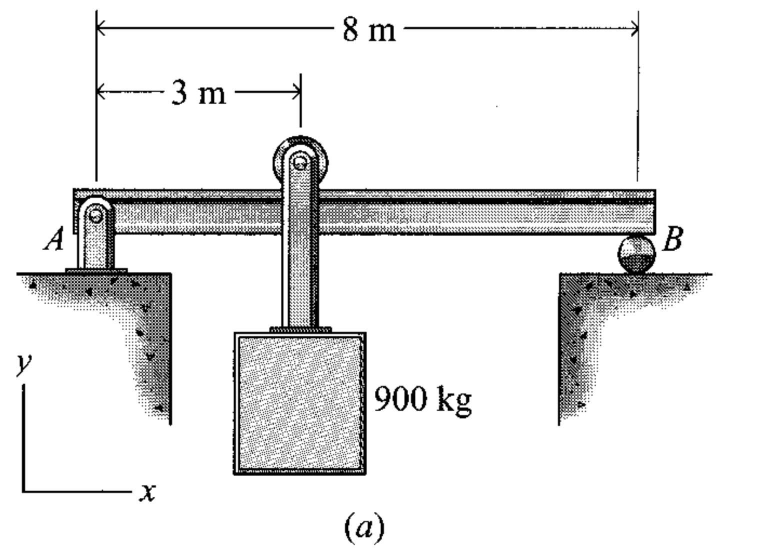


Figure 1-6(a)

1.3 Equilibrium of a rigid body

- Example problem 1-4
 - Forces on member BH

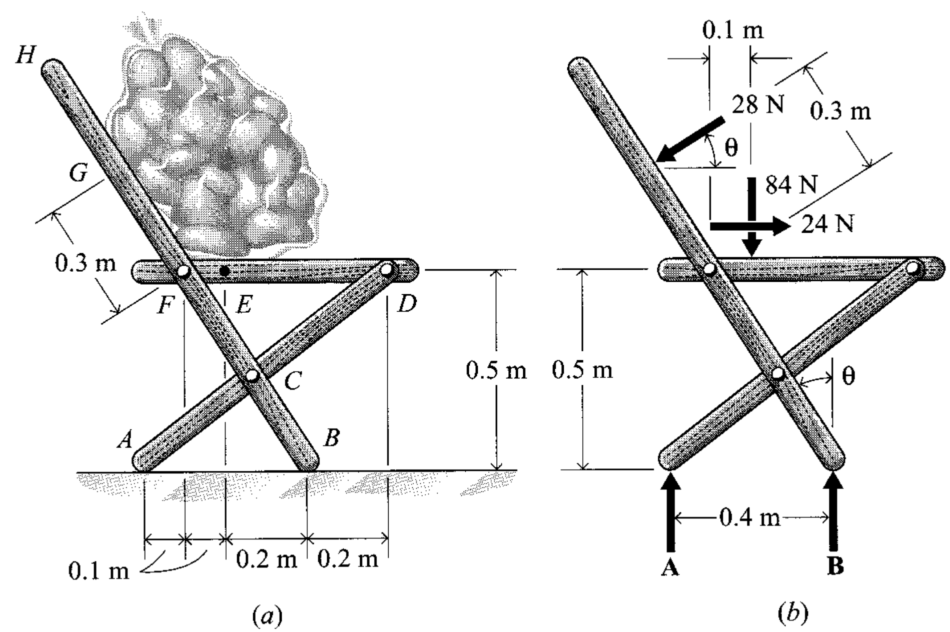


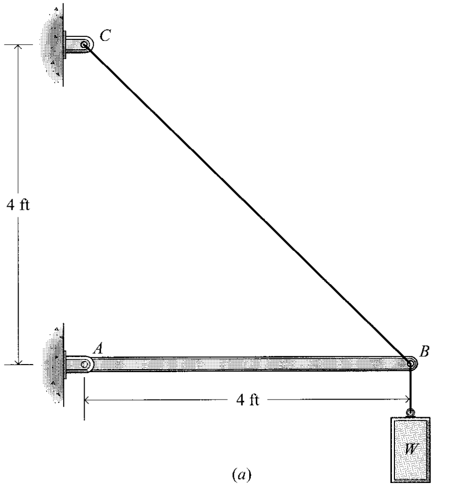
Figure 1-8

1.4 Equilibrium of a deformable body

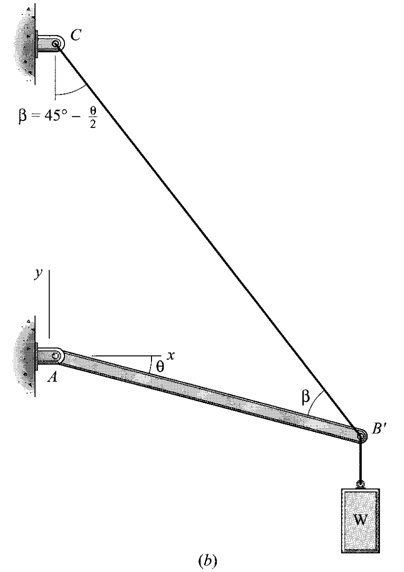
- Considerations
  - Equation of equilibrium
  - Force-deformation relationship
  - Deformation

- Example problem 1-8
  - Tension in the deformable wire at k = 5000 lb/in, 2500 lb/in, and 1000 lb/in (W=5000 lb)

→ Tension (force) depends on the force-deformation relationship of the deformable body



(a)



(b)

1.5 Internal forces

- Equilibrium of parts of a body

- If a whole body is in equilibrium any part of the body is also in equilibrium.

- Forces distributed on a section can be represented by a resultant force.

$$\sum F = 0: \quad F_1 + F_2 + R = 0$$

$$\sum M_C = 0: M_1 + M_2 + C = 0$$

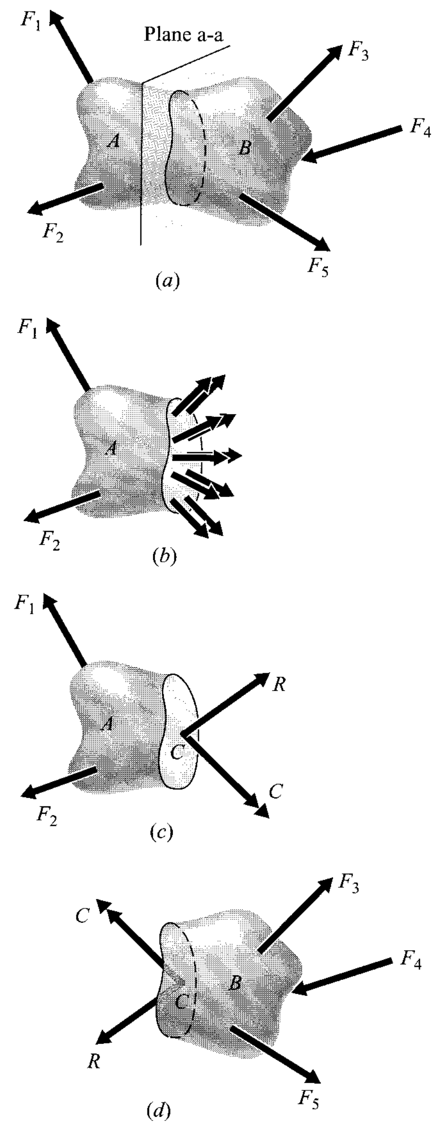


Figure 1-17

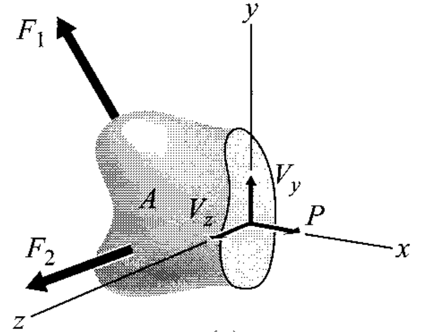
1.5 Internal forces

• Internal forces in a section

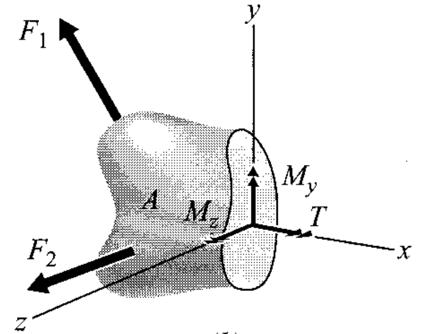
- Select an *xyz*-coordinate system in which *x* is perpendicular to the section and *y* and *z* lie in the section.

The components of *R* and *C* perpendicular to the section are called **normal force** (P) and **twisting couple** (T; twisting moment or torque).

- The components of *R* and *C* lying in the section are called **shear forces** (V_y, V_z) and **bending couples** (M_y, M_z; bending moments).



(a)

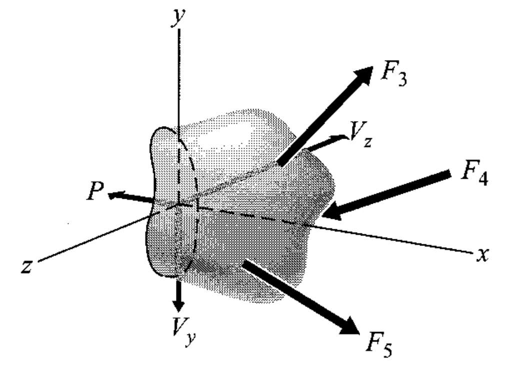


(b)

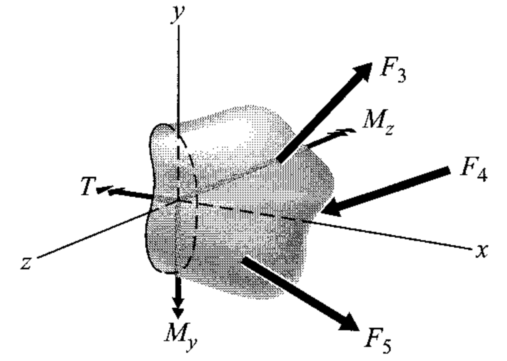
1.5 Internal forces

-A section is called a positive (negative) section when its outward normal points in a positive coordinate direction.

- The component of *R* or *C* is defined as positive if both the section direction and the component direction are positive or negative.



(*c*)



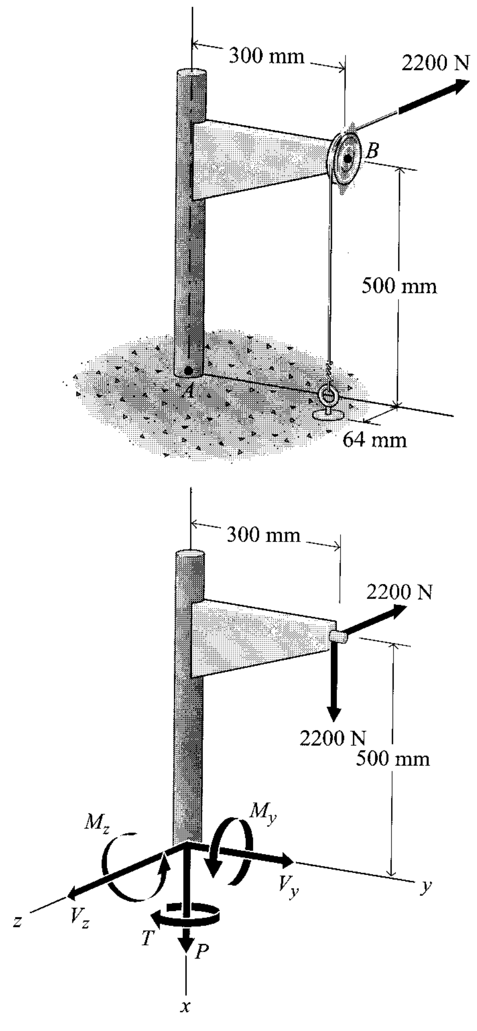
(*d*)

1.5 Internal forces

- Example problem 1-9

- Internal force components on a section A

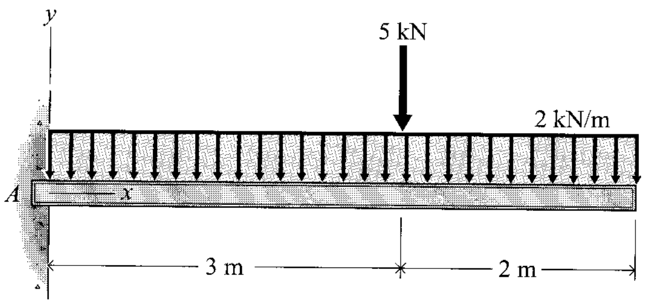
- Internal moment components on a section A



1.5 Internal forces

• Example problem 1-10

- Support reaction force and moment at A



- Internal force and moment on a section 4 m
  to the right of the support A

1.5 Internal forces

- Example problem 1-11

- Internal force and moment on a mid-point section between D and F