材料と部材の力学

Chap.1: Introduction
Chap.2: Statics of Particles
Chap.3: Statics of Rigid Bodies

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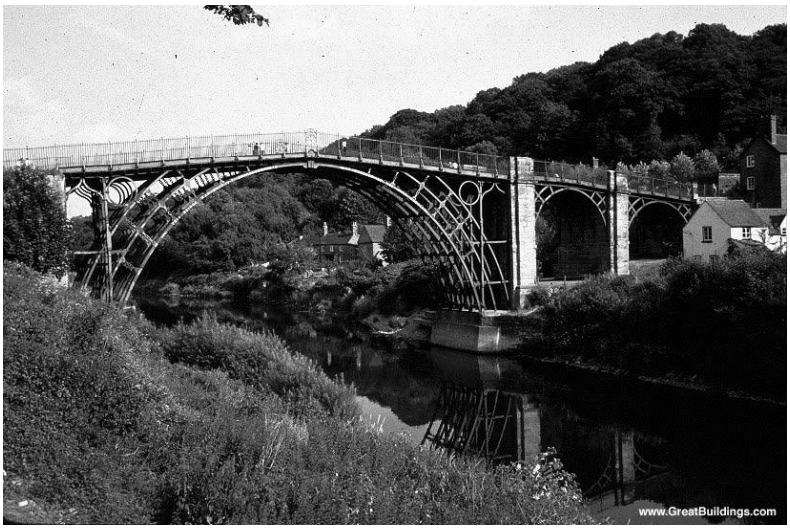
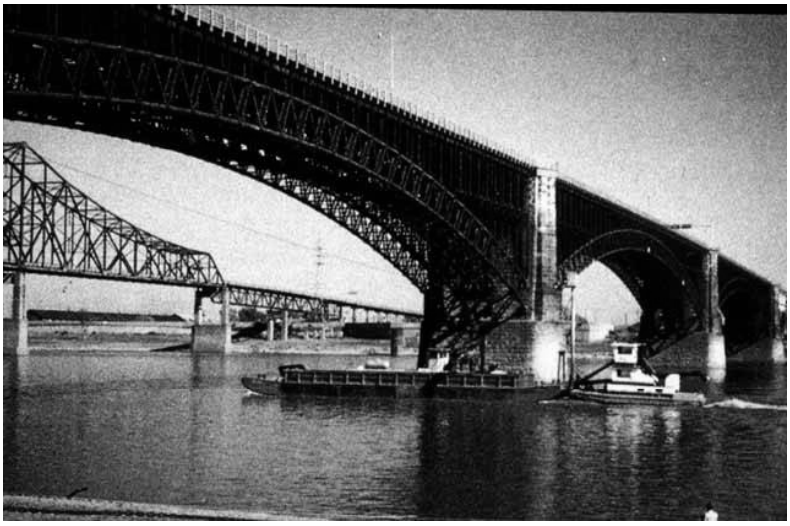


Coalbrookdale Bridge 英国 1779年 支間30.5m

最初の鉄製の橋

2



イーズ橋 米国 1874年 支間158.5m

初期の鉄製の橋

3

Brooklyn Bridge 米国 1883年 支間486m

ケーブルを使用した吊橋

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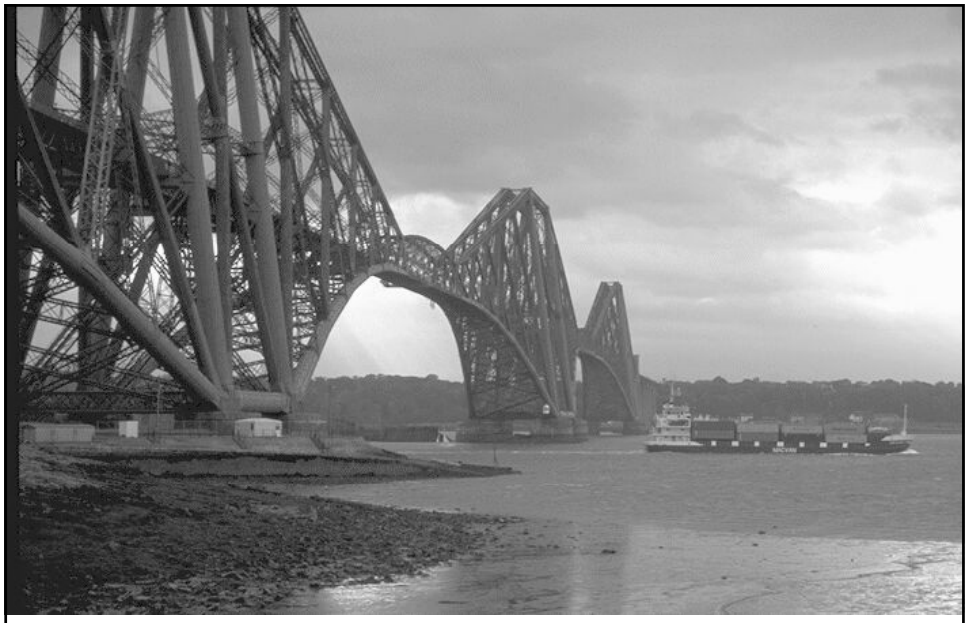

フォース鉄道橋 英国 1890年 支間512m

http://structure.cande.iwate-u.ac.jp/miyamoto/bridge/image/Forthbr.jpg

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餘部鉄橋 1907年

6

Akashi (1998)　960 + 1991 + 960 (The Largest Suspension Bridge)

7

主塔より

8

Tatara (1999)　　270 + 890 + 320
(The Largest Cable Stayed Bridge)

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今後の大規模橋梁プロジェクト

Tokyo Bay

新しい橋梁用高性能鋼材
（BHS）の適用

東京湾第3航路橋
中央径間 : 760m
(4 Truss Type Bridges)

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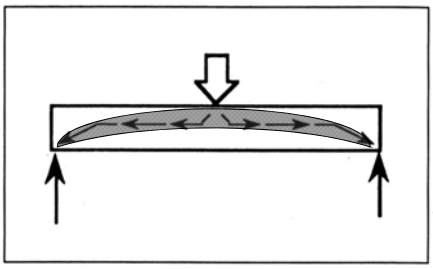
力学的に形状が決定される構造例(1)

Determination of Shapes of Structural Components
Based on Mechanics



アーチ構造，ドーム構造

石造で長スパンを考えると
アーチになる

通潤橋（1854）

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力学的に形状が決定される構造例(2)

Determination of Shapes of Structural Components
Based on Mechanics

なぜアーチ形状？
車両の形に合せたら？

Tunnel

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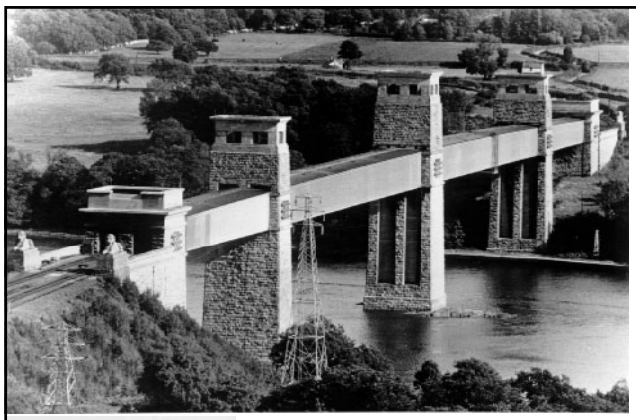
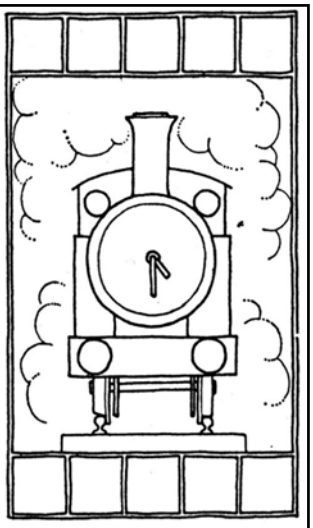


Britannia Bridge



Britannia bridge: tubular box beam.

たわみをおさえるために桁高が大きくなり，
吊橋 → 箱断面桁橋

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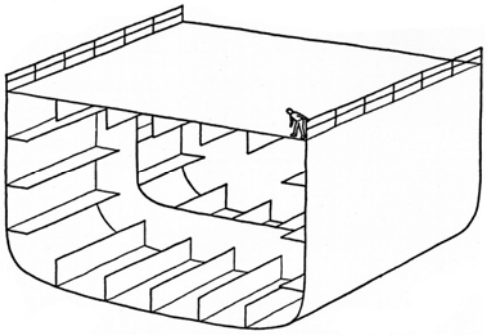
日本丸

- ■総トン数／21,903トン
- ■全長／166.6m
- ■全幅／24.0m
- ■客室数／202室
- ■乗客数／600名
- ■就航年：1990年

断面の構成は
箱断面の桁橋と同じ



Engineering shell structures such as ships and aircraft generally use both stringers and ribs or bulkheads. This is a diagram of the Isherwood construction often used in oil tankers.

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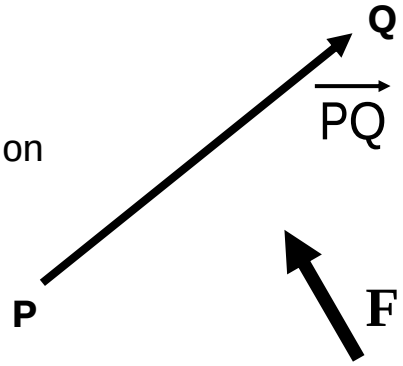
1. Force

A Force represents the action of one body on another

i point of application
ii its magnitude
iii its direction



We will study the conditions of rest or motion of particles and rigid bodies.

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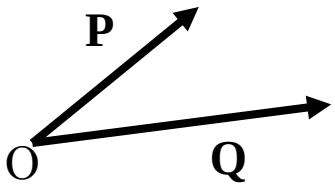
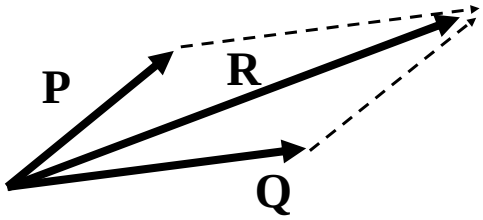
Addition of Vectors

$$\mathbf{P} + \mathbf{Q} = \mathbf{Q} + \mathbf{P}$$



The parallelogram law for the addition of forces



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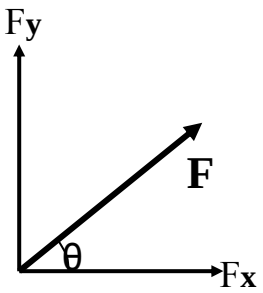
Rectangular components of a force : unit vectors

$$\begin{cases} \mathbf{F} = F_x\,\mathbf{i}_x + F_y\,\mathbf{i}_y \\ \mathbf{F} = F_x\,\mathbf{i}_x + F_y\,\mathbf{i}_y + F_z\,\mathbf{i}_z \\ \mathbf{F} = F_i\,\mathbf{i}_i \end{cases}$$



$$F_x = F\cos\theta$$

$$F_y = F\sin\theta$$

$$\tan\theta = \frac{F_y}{F_x}$$

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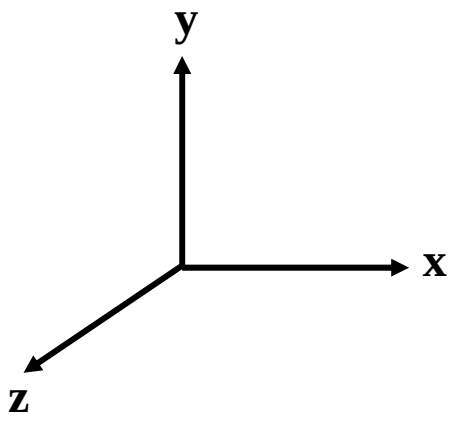
2.Coordination system

The system of rectangular coordination
→ **Right Hand system**



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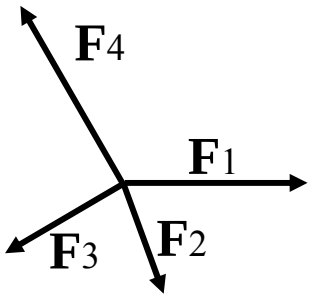
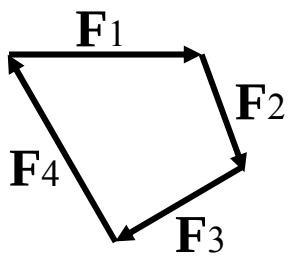
3. Equilibrium of particles



$$\mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3 + \cdots + \mathbf{F}_n = 0$$



$$\Sigma \mathbf{F}_x = \mathbf{F}_x^1 + \mathbf{F}_x^2 + \mathbf{F}_x^3 + \cdots + \mathbf{F}_x^n = 0$$

$$\Sigma \mathbf{F}_y = \mathbf{F}_y^1 + \mathbf{F}_y^2 + \mathbf{F}_y^3 + \cdots + \mathbf{F}_y^n = 0$$

$$\Sigma \mathbf{F}_z = \mathbf{F}_z^1 + \mathbf{F}_z^2 + \mathbf{F}_z^3 + \cdots + \mathbf{F}_z^n = 0$$

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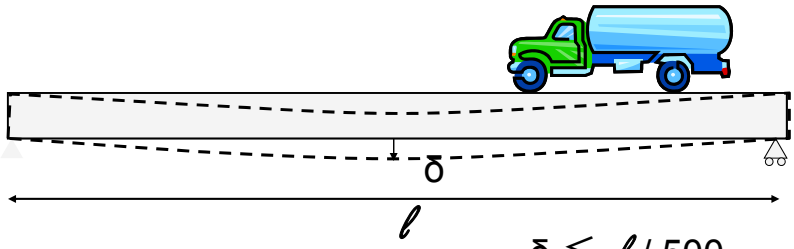
1. Rigid bodies

Most of bodies are assumed to be rigid ··· rigid body

Actual structures are never absolutely rigid

But these deformations are usually small

And do not affect the equilibrium or motion



$\delta \leqq \ell / 500$

Usually $\delta \leqq \ell / 1000$

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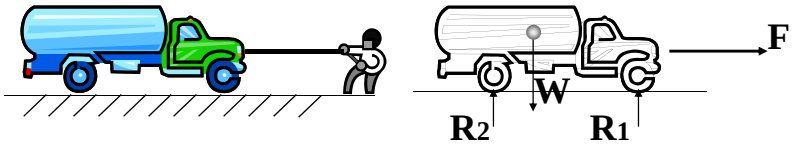
Behavior of rigid body due to external forces

Free body diagram



Translation

Rotation

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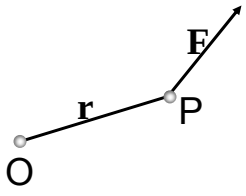
2. Moment

Moment of a force about a point

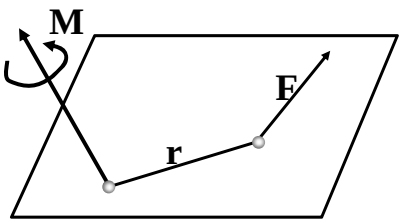
$$\begin{cases} \mathbf{M} = \mathbf{r} \times \mathbf{F} \\ \quad = \sum_i \sum_j \mathbf{e}_{ijk}\, \mathbf{r}_i\, \mathbf{F}_j \end{cases} \qquad \begin{cases} \mathbf{M} = M_k\, \mathbf{i}_k \\ \quad = M_x\, \mathbf{i}_x + M_y\, \mathbf{i}_y + M_z\, \mathbf{i}_z \end{cases}$$



$$M_x = r_y F_z - r_z F_y$$

$$M_y = r_z F_x - r_x F_z$$

$$M_z = r_x F_y - r_y F_x$$



$$\mathbf{M} = \begin{vmatrix} \mathbf{i}_x & \mathbf{i}_y & \mathbf{i}_z \\ \mathbf{r}_x & \mathbf{r}_y & \mathbf{r}_z \\ \mathbf{F}_x & \mathbf{F}_y & \mathbf{F}_z \end{vmatrix}$$

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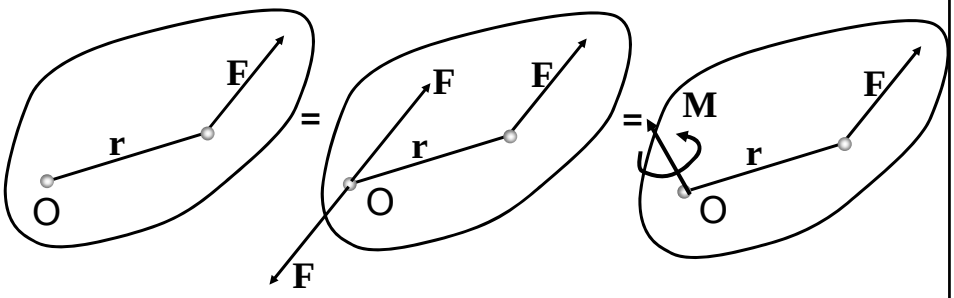
3. Equilibrium of Rigid Bodies

Reduction of a system of forces to one force to one moment



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Necessary and sufficient conditions for the equilibrium

$$\Sigma \mathbf{F} = 0$$

$$\Sigma \mathbf{M} = \Sigma(\mathbf{r} \times \mathbf{F}) = 0$$

$\Sigma \mathbf{F}_x = 0$ $\quad$ $\Sigma \mathbf{F}_y = 0$ $\quad$ $\Sigma \mathbf{F}_z = 0$

$\Sigma \mathbf{M}_x = 0$ $\quad$ $\Sigma \mathbf{M}_y = 0$ $\quad$ $\Sigma \mathbf{M}_z = 0$

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