CHAPTER

Engineering Mechanics: Statics Tenth Edition

GENERAL PRINCIPLES

UMBC

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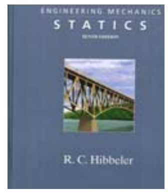
•College of Engineering •Department of Mechanical Engineering



by
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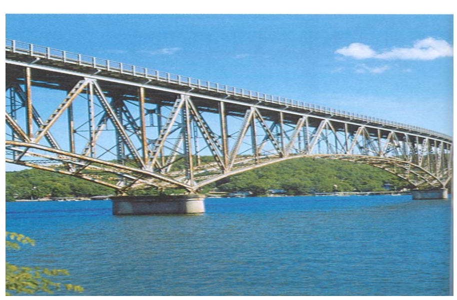
SPRING 2007

ENES 110 – Statics

Department of Mechanical Engineering
University of Maryland Baltimore County

Statics, Units, Calculations & problem Solving

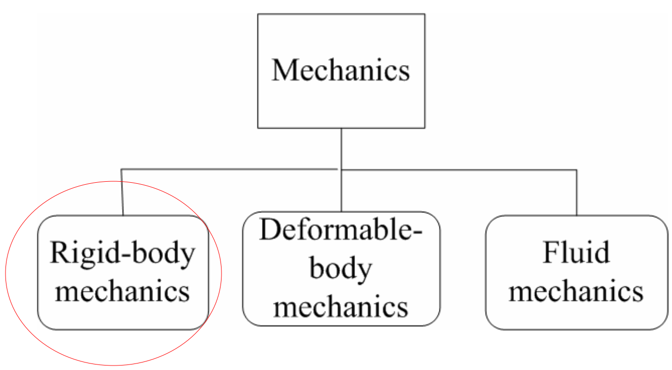
- Students will be able to:
  - Use Law of Sines and Cosines
  - Solve system of simultaneous equations
  - Round the final answer appropriately



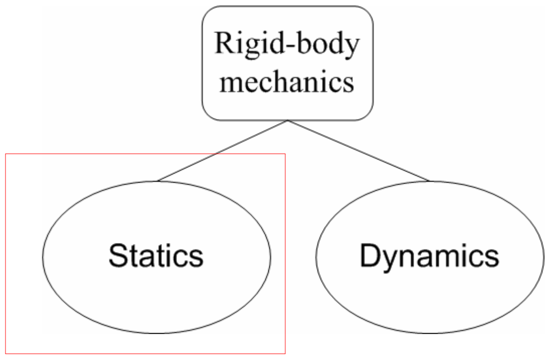
Mechanics

Mechanics can be defined as that branch of the physical sciences concerned with the state of rest or motion of bodies that are subjected to the action of forces.

Mechanics



Mechanics



Mechanics

WHAT MAY HAPPEN IF STATICS IS NOT APPLIED PROPERLY?

Rigid-Body Mechanics

- Statics
  – Deals with the equilibrium of bodies, that is, those that are either at rest or move with a constant velocity.
- Dynamics
  – Is concerned with the accelerated motion of bodies.

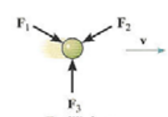
Fundamental Concepts

- Basic Quantities
  – Length (m, ft)
  – Time (h, s, min)
  – Mass (Kg, slug)
  – Force (N, lb)

Fundamental Concepts

- Idealization
  - – Particle
    - A particle has a mass but a size that can be neglected.
  - – Rigid Body
    - A rigid body can be considered as a combination of a large umber of particles in which all the particles remain at fixed distance from one another both before and after applying a load.
  - – Concentrated Force
    - Represents the effect of a loading which is assumed to act at a point on a body.

Fundamental Concepts



Equilibrium

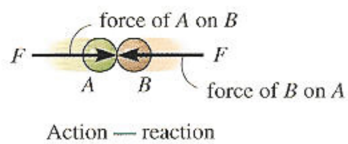
- Newton's Three Laws of Motion
  - – First Law
    - A particle originally at rest, or moving in a straight line with constant velocity, will remain in this state.
  - – Second Law
    - A particle acted upon by an unbalanced force **F** experiences an acceleration **a** that has the same direction as the force and a magnitude that is directly proportional to the force.

Accelerated motion

$$\mathbf{F} = m\mathbf{a} \qquad (1\text{-}1)$$

Fundamental Concepts

- Newton's Three Laws of Motion (cont'd)
  – Third Law
    - The mutual forces of action and reaction between two particles are equal, opposite, and collinear.



Fundamental Concepts

- Newton's Law of Gravitational Attraction

$$F = G\frac{m_1 m_2}{r^2} \qquad (1\text{-}2)$$

F = force of gravitation between the two particles
G = universal constant of gravitation (= 66.73×10^{-12} m^3/kg·s^2)
m_1 m_2 = mass of each of the particles
r = distance between the two particles

Fundamental Concepts

- Newton’s Law of Gravitational Attraction
  - Weight
    - The weight of a particle having a mass $m_1 = m$ (assuming that the mass of the earth $m_2 = M_e$) can be given as

$$W = F = G\frac{mM_e}{r^2}$$

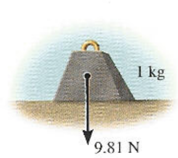
    - Or

$$W = mg \qquad (1\text{-}3)$$

    - where

$$g = G\frac{M_e}{r^2}$$

Units of Measurements

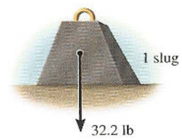


- SI Units
  - The international System of Units, abbreviated SI after French “System International d’Unites.”
  - The unit of force F or W is called newton (N).
  - It is derived from $\mathbf{F} = m\mathbf{a}$.
  - Thus

$$W = mg \qquad (g = 9.81\,\text{m/s}^2) \qquad (1\text{-}4)$$

Units of Measurements

- U.S. Customary Units
  - In the U.S. Customary systems of units (FPS) length is measured in feet (ft), force in pounds (lb), and time in seconds (s).
  - The unit of mass is called slug.
  - It is derived from **F** = *m**a***.
  - Therefore,



$$m = \frac{W}{g} \qquad (g = 32.2\ \text{ft/s}^2) \qquad (1\text{-}5)$$

Units of Measurements

- System of Units

Name	Length	Time	Mass	Force
International System of Units (SI)	meter (m)	second (s)	kilogram (kg)	newton* (N) $\left(\frac{\text{kg}\cdot\text{m}}{\text{s}^2}\right)$
U.S. Customary (FPS)	foot (ft)	second (s)	slug* $\left(\frac{\text{lb}\cdot\text{s}^2}{\text{ft}}\right)$	pound (lb)

*Derived unit.

Units of Measurements

- Conversion of Units
  - In FPS system,
    - 1 ft = 12 in. (inches)
    - 5280 ft = 1 mi (mile)
    - 1000 lb = 1 kip (kilo-pound)
    - 2000 lb = 1 ton

TABLE 1–2 • Conversion Factors

Quantity	Unit of Measurement (FPS)	Equals	Unit of Measurement (SI)
Force	lb		4.448 2 N
Mass	slug		14.593 8 kg
Length	ft		0.304 8 m

Units of Measurements

- Prefixes

TABLE 1–3 • Prefixes

	Exponential Form	Prefix	SI Symbol
Multiple			
1 000 000 000	10^9	giga	G
1 000 000	10^6	mega	M
1 000	10^3	kilo	k
Submultiple			
0.001	10^{-3}	milli	m
0.000 001	10^{-6}	micro	μ
0.000 000 001	10^{-9}	nano	n

Units of Measurements

- International System of Units (SI)
  - No Plurals (e.g., m = 5 kg not kgs)
  - Separate Units with a • (e.g., meter second = m • s)
  - Most symbols are in lowercase.
  - Some exceptions are N, Pa, M and G.
  - Exponential powers apply to units, e.g., cm • cm = cm^2
  - Compound prefixes should not be used.
  - Other rules are given in your textbook

Numerical Calculations

- Must have dimensional "homogeneity." Dimensions have to be the same on both sides of the equal sign, (e.g. distance = speed × time.)
- Use an appropriate number of significant figures (3 for answer, at least 4 for intermediate calculations). Why?

Numerical Calculations

- Be consistent when rounding off
  - greater than or equal to 5, round up (3528 → 3530).
  - smaller than 5, round down (0.03521 → 0.0352).

Numerical Calculations

- Example 1

Convert the quantities 300 lb · s and 52 slug/ft^3 to appropriate SI units.

Solution

Using Table 1–2, 1 lb = 4.448 2 N.

$$300\text{ lb}\cdot\text{s} = 300\text{ lb}\cdot\text{s}\left(\frac{4.448\,2\text{ N}}{\text{lb}}\right)$$

$$= 1334.5\text{ N}\cdot\text{s} = 1.33\text{ kN}\cdot\text{s} \qquad \textit{Ans.}$$

Also, 1 slug = 14.593 8 kg and 1 ft = 0.304 8 m.

$$52\text{ slug/ft}^3 = \frac{52\text{ slug}}{\text{ft}^3}\left(\frac{14.593\,8\text{ kg}}{1\text{ slug}}\right)\left(\frac{1\text{ ft}}{0.304\,8\text{ m}}\right)^3$$

$$= 26.8(10^3)\text{kg/m}^3$$

$$= 26.8\text{ Mg/m}^3 \qquad \textit{Ans.}$$

Numerical Calculations

- Example 2

Convert 2 km/h to m/s. How many ft/s is this?

Solution

Since 1 km = 1000 m and 1 h = 3600 s, the factors of conversion are arranged in the following order, so that a cancellation of the units can be applied:

$$2\text{ km/h} = \frac{2\text{ km}}{\text{h}}\left(\frac{1000\text{ m}}{\text{km}}\right)\left(\frac{1\text{ h}}{3600\text{ s}}\right)$$

$$= \frac{2000\text{ m}}{3600\text{ s}} = 0.556\text{ m/s} \qquad \textit{Ans.}$$

From Table 1–2, 1 ft = 0.3048 m. Thus

$$0.556\text{ m/s} = \frac{0.556\text{ m}}{\text{s}}\,\frac{1\text{ ft}}{0.3048\text{ m}}$$

$$= 1.82\text{ ft/s} \qquad \textit{Ans.}$$

Numerical Calculations

- Example 3

Evaluate each of the following and express with SI units having an appropriate prefix: (a) (50 mN)(6 GN), (b) (400 mm)(0.6 MN)^2, (c) 45 MN^3/900 Gg.

Solution

First convert each number to base units, perform the indicated operations, then choose an appropriate prefix (see Rule 6 on p. 9).

Part (a)

$$(50\text{ mN})(6\text{ GN}) = [50(10^{-3})\text{ N}][6(10^{9})\text{ N}]$$

$$= 300(10^{6})\text{ N}^2$$

$$= 300(10^{6})\text{ N}^2\left(\frac{1\text{ kN}}{10^3\text{ N}}\right)\left(\frac{1\text{ kN}}{10^3\text{ N}}\right)$$

$$= 300\text{ kN}^2 \qquad \textit{Ans.}$$

Note carefully the convention kN^2 = (kN)^2 = 10^6 N^2 (Rule 4 on p. 9).

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Numerical Calculations

- Example 3 (cont'd)

TABLE 1–3 • Prefixes

	Exponential Form	Prefix	SI Symbol
Multiple			
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1 000	10^3	kilo	k
Submultiple			
0.001	10^{-3}	milli	m
0.000 001	10^{-6}	micro	μ
0.000 000 001	10^{-9}	nano	n

Numerical Calculations

- Example 3 (cont'd)

Part (b)

$$(400\text{ mm})(0.6\text{ MN})^2 = [400(10^{-3})\text{ m}][0.6(10^6)\text{ N}]^2$$
$$= [400(10^{-3})\text{ m}][0.36(10^{12})\text{ N}^2]$$
$$= 144(10^9)\text{ m}\cdot\text{N}^2$$
$$= 144\text{ Gm}\cdot\text{N}^2 \qquad \textit{Ans.}$$

We can also write

$$144(10^9)\text{m}\cdot\text{N}^2 = 144(10^9)\text{m}\cdot\text{N}^2\left(\frac{1\text{ MN}}{10^6\text{ N}}\right)\left(\frac{1\text{ MN}}{10^6\text{ N}}\right)$$
$$= 0.144\text{ m}\cdot\text{MN}^2$$

Part (c)

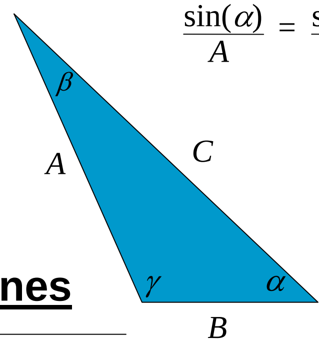
$$45\text{ MN}^3/900\text{ Gg} = \frac{45(10^6\text{ N})^3}{900(10^6)\text{ kg}}$$
$$= 0.05(10^{12})\text{ N}^3/\text{kg}$$
$$= 0.05(10^{12})\text{ N}^3\left(\frac{1\text{ kN}}{10^3\text{ N}}\right)^3\frac{1}{\text{kg}}$$
$$= 0.05(10^3)\text{ kN}^3/\text{kg}$$
$$= 50\text{ kN}^3/\text{kg} \qquad \textit{Ans.}$$

Here we have used Rules 4 and 8 on p. 9.

Law of Sines and Cosines

Law of Sines

$$\frac{\sin(\alpha)}{A} = \frac{\sin(\beta)}{B} = \frac{\sin(\gamma)}{C}$$



Law of Cosines

$$C = \sqrt{A^2 + B^2 - 2AB\cos(\gamma)}$$

Properties of Right Triangles

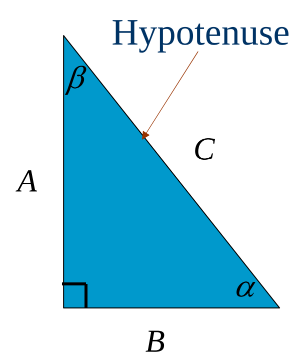
Remember – **SOH-CAH-TOA**
sin is opposite/hypotenuse, cosine is adjacent/hypotenuse, and tangent is opposite/adjacent.

$A^2 + B^2 = C^2$ (Pythagorean Theorem)

$$\sin(\alpha) = \frac{A}{C} \qquad \cos(\beta) = \frac{A}{C}$$

$$\cos(\alpha) = \frac{B}{C} \qquad \sin(\beta) = \frac{B}{C}$$

$$\tan(\alpha) = \frac{A}{B} \qquad \tan(\beta) = \frac{B}{A}$$



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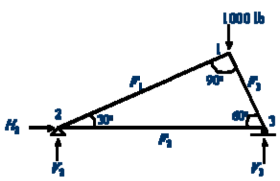
Simultaneous Equations

- Most calculators can do this or can be programmed to do this.
- Many different methods available.
- Beyond scope of class – examples in text.



$$
\begin{aligned}
-0.866F_1 \quad\quad\quad + 0.5F_3 \quad\quad\quad &= 0 \\
-0.5F_1 \quad\quad\quad - 0.866F_3 \quad\quad\quad &= 1000 \\
0.866F_1 + F_2 \quad\quad\quad + H_2 \quad\quad &= 0 \\
0.5F_1 \quad\quad\quad\quad\quad + V_2 &= 0 \\
-F_2 - 0.5F_3 \quad\quad\quad &= 0 \\
0.866F_3 \quad\quad\quad + V_3 &= 0
\end{aligned}
$$

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