Faculty of Engineering
Civil Engineering Department
2nd Class

Strength of Materials
(Mechanics of Materials)
(SI Units)

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2017-2018

Mechanics of Material I

Text Books

- Mechanics of Materials, 10th edition (SI version), by: R. C. Hibbeler, 2017
- Mechanics of Materials, 2nd edition (SI version), by: E. Popov, 1990

References

- Strength of Materials, fifth edition,(SI units), Schaum's outlines, by: W. Nash and M. Potter, 1977
- Mechanics of Materials, eighth edition,(SI units), by: James M. Gere, and Barry J. Goodno, 2013.
- Strength of Materials Lectures, Civil Engineering Department, Faculty of Eng., UOM, by: Dr Ali Al-Ghalib, 2014.

Syllabus of Mechanics of Material I – Course No. (50601202):

Ch1. Stress, Axial Loads

The concept of the stress, General stresses in a space element , Types of stresses, Riveted (Bolted) Joints, Allowable stresses; Factor of Safety,

Ch2. Strain, Hooke's Law, Axial Load Problems

True Stress- strain diagram, Ductile and Brittle Materials, Deflection of Axially Loaded Rods (applied within elastic range only), Statically indeterminate members (axially loaded only), Problems Involving Temperature Changes (Thermal changes), Poisson's Ratio, Generalized Hooke's Law, Shear Strain, Hooke's Law in Shear,

Ch3. Axial Force, Shear and Bending moment

Types of supports, Types of loadings, Classification of beams according to their supporting system, Classification of beams according to their analysis procedure, Calculations of beams' reactions, Internal forces and moments in beams, Shear and moment diagrams by equations, Shear and moment diagrams by summation approach,

Ch4. Torsion

Torsion formula of circular sections, Polar moment of inertia, Hollow circular sections, Statically Indeterminate Problems, Torsion of Noncircular Members, Thin-walled members with open cross sections Thin-walled members with open cross sections

Ch5. Pure Bending of Beams

Curvature of a beam, Bending formula, Elastic section modulus, Beams of Two Materials, Stress Distribution in Composite Sections (Method of Transformed section).

COURSE OBJECTIVES (Learning Outcomes):

- Analyze and design structural members subjected to tension, compression, torsion, bending and combined stresses using the fundamental concepts of stress, strain and elastic behavior of materials.
- Utilize appropriate materials in design considering engineering properties, sustainability, cost and weight.
- Perform engineering work in accordance with ethical and economic constraints related to the design of structures and machine parts.

INTRODUCTION

Strength of materials is a branch of applied mechanics that deals with the behavior of solid bodies subjected to various types of loading. Other names for this field of study are mechanics of materials and solid mechanics. The solid bodies considered in this book include bars with axial loads, shafts in torsion, beams in bending, and columns in compression. The principal objective of mechanics of materials is to determine the stresses, strains, and displacements in structures and their components due to the loads acting on them. If we can find these quantities for all values of the loads up to the loads that cause failure, we will have a complete picture of the mechanical behavior of these structures

SYMBOLS AND SI UNITS

GREEK ALPHABET

Α	α	Alpha	Ν	ν	Nu
Β	β	Beta	Ξ	ξ	Xi
Γ	γ	Gamma	Ο	o	Omicron
Δ	δ	Delta	Π	π	Pi
Ε	ε	Epsilon	Ρ	ρ	Rho
Ζ	ζ	Zeta	Σ	σ	Sigma
Η	η	Eta	Τ	τ	Tau
Θ	θ	Theta	Υ	υ	Upsilon
Ι	ι	Iota	Φ	ϕ	Phi
Κ	κ	Kappa	Χ	χ	Chi
Λ	λ	Lambda	Ψ	ψ	Psi
Μ	μ	Mu	Ω	ω	Omega

Prefixes	Value	Standard form	Symbol
Tera	1 000 000 000 000	10^{12}	T
Giga	1 000 000 000	10^{9}	G
Mega	1 000 000	10^{6}	M
Kilo	1 000	10^{3}	k
deci	0.1	10^{-1}	d
centi	0.01	10^{-2}	c
milli	0.001	10^{-3}	m
micro	0.000 001	10^{-6}	µ
nano	0.000 000 001	10^{-9}	n
pico	0.000 000 000 001	10^{-12}	p

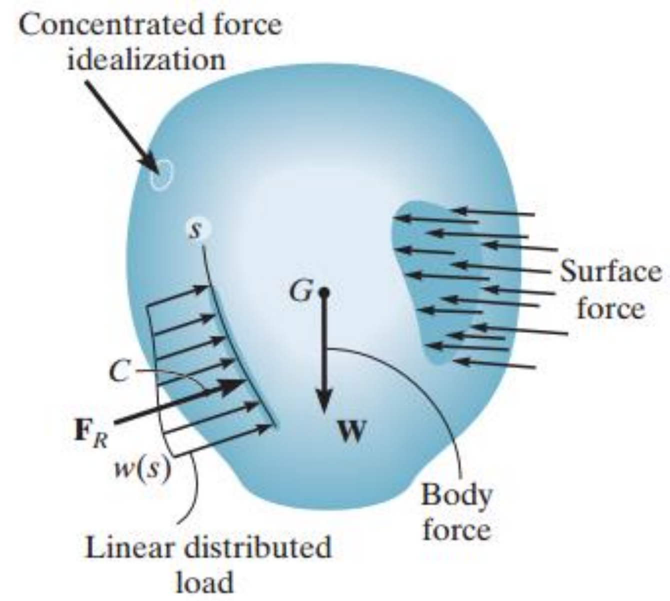
Quantity	U.S. Customary	SI Equivalent
Force	lb. kip	4.448N 4.448kN
Length	in ft	25.4mm 0.3048m
Area	in^2 ft^2	$645.2mm^2$ $0.0929m^2$
Stress	Ib/in^2 (psi)	$6.895kN/m^2$ (kPa)

CHAPER ONE – STRESS, AXIAL LOADS

Static Review:

Since statics has an important role in both the development and application of mechanics of materials, it is very important to have a good grasp of its fundamentals. For this reason we will review some of the main principles of statics that will be used throughout the text.

External Loads: A body is subjected to only two types of external loads; namely, surface forces or body forces.

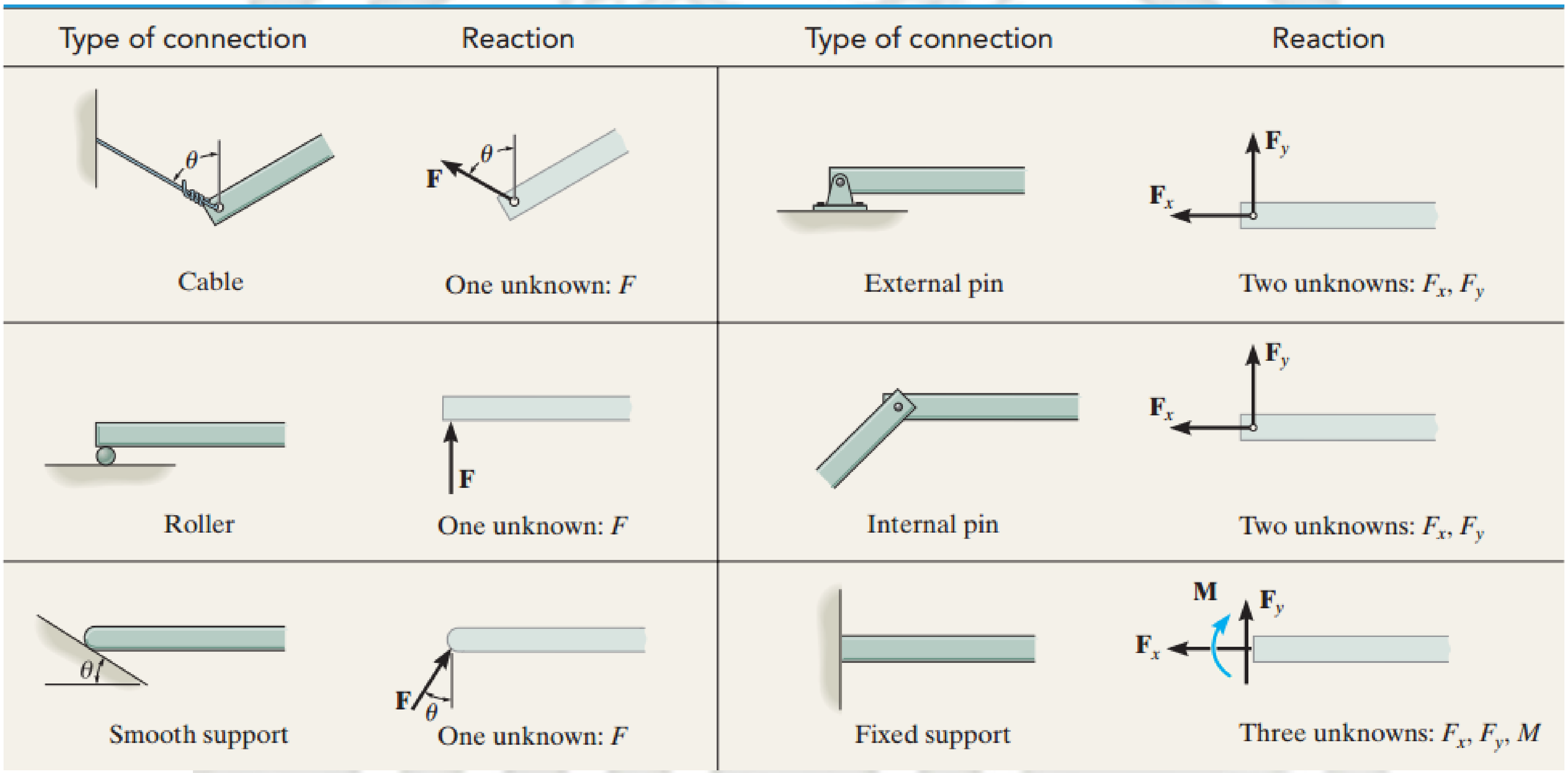


Surface Forces: Surface forces are caused by the direct contact of one body with the surface of another. In all cases these forces are distributed over the area of contact between the bodies. If this area is small in comparison with the total surface area of the body, then the surface force can be idealized as a single concentrated force, which is applied to a point on the body. If the surface loading is applied along a narrow strip of area, the loading can be idealized as a linear distributed load, w(s). Here the loading is measured as having an intensity of force/length along the strip and is represented graphically by a series of arrows along the lines. The resultant force of w(s) is equivalent to the area under the distributed loading curve, and this resultant acts through the centroid C or geometric center of this area.

Body Forces: A body force is developed when one body exerts a force on another body without direct physical contact between the bodies. Examples include the effects caused by the earth's gravitation or its electromagnetic field. In the case of gravitation, this force is called the weight of the body and acts through the body's center of gravity.

Support Reactions:

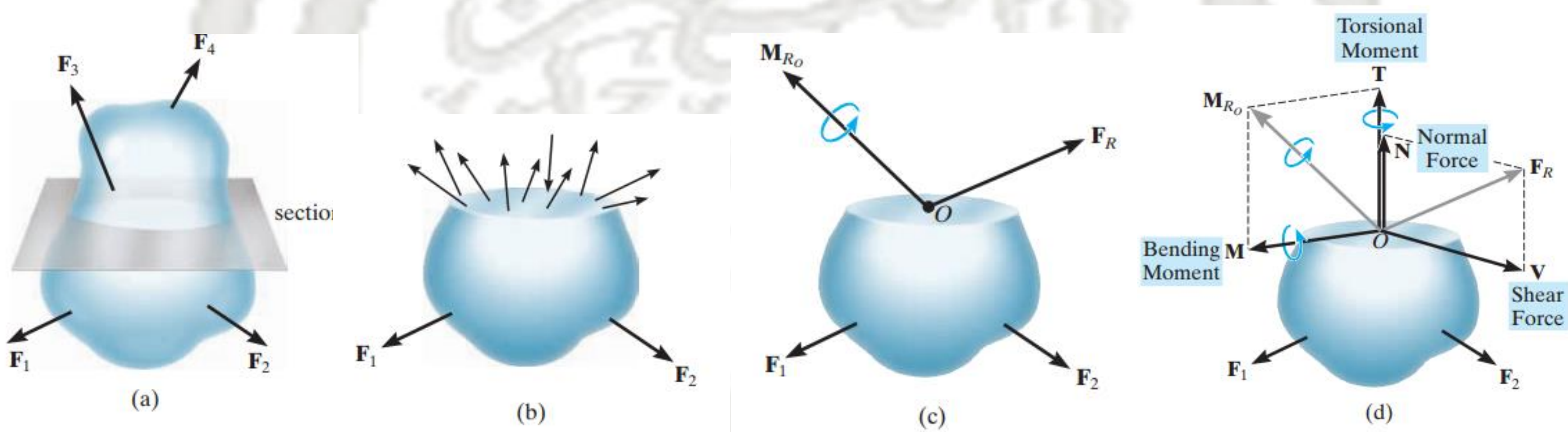
The general rule is: **if the support prevents translation in a given direction, then a force must be developed on the member in that direction. Likewise, if rotation is prevented, a couple moment must be exerted on the member.** For example, the roller support only prevents translation perpendicular or normal to the surface. Hence, the roller exerts a normal force F on the member at its point of contact. Since the member can freely rotate about the roller, a couple moment cannot be developed on the member.



Equations of Equilibrium: Equilibrium of a body requires both a **balance of forces**, to prevent the body from translating or having accelerated motion along a straight or curved path, and a **balance of moments**, to prevent the body from rotating.

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

Internal Resultant Loadings and free body diagram



Normal force, N. This force acts perpendicular to the area. It is developed whenever the external loads tend to push or pull on the two segments of the body.

Shear force, V. The shear force lies in the plane of the area and it is developed when the external loads tend to cause the two segments of the body to slide over one another.

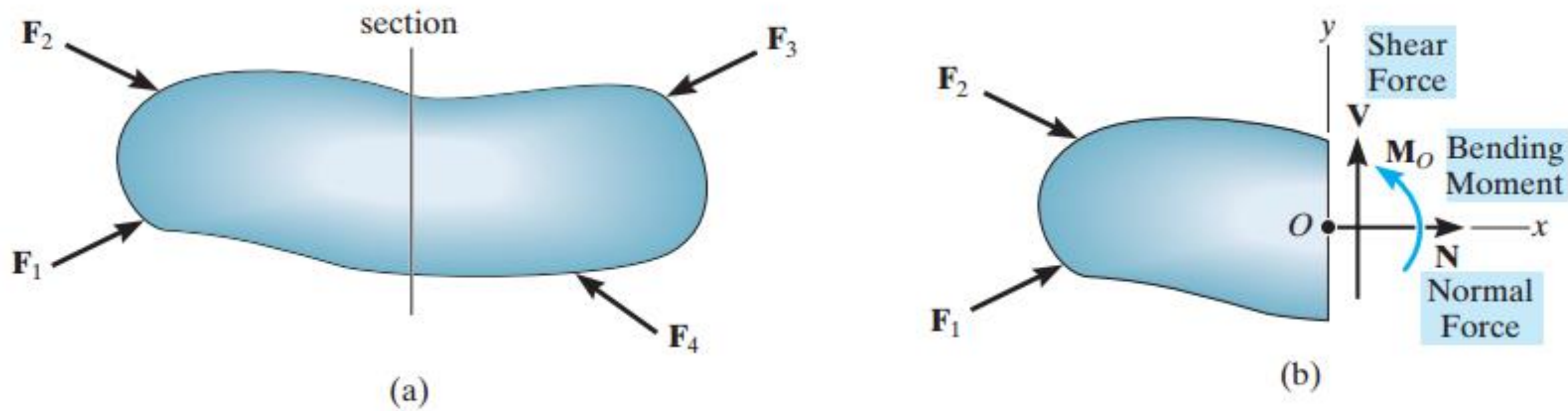
Torsional moment or torque, T. This effect is developed when the external loads tend to twist one segment of the body with respect to the other about an axis perpendicular to the area.

Bending moment, M. The bending moment is caused by the external loads that tend to bend the body about an axis lying within the plane of the area.

Coplanar Loadings:

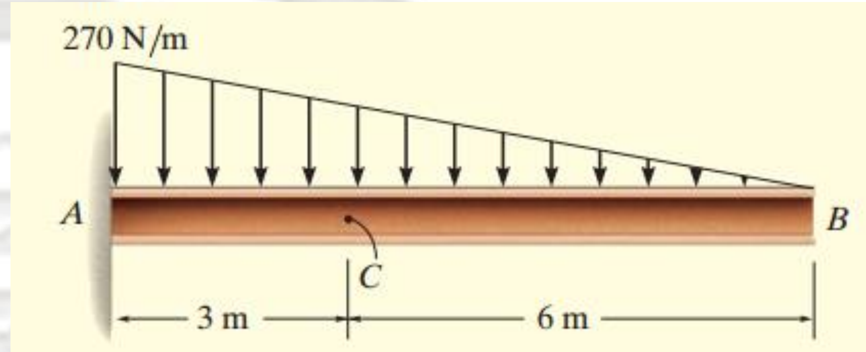
If the body is subjected to a coplanar system of forces, then only normal force, shear force, and bending moment components will exist at the section.

$$\Sigma F_x = 0$$
$$\Sigma F_y = 0$$
$$\Sigma M_O = 0$$



EXAMPLE 1-1

Determine the resultant internal loadings acting on the cross section at C of the cantilevered beam shown in the Figure.



$$\frac{w}{6} = \frac{270}{9} \rightarrow w = 180 N/m$$

$$F = \frac{1}{2} \times 180 \times 6 = 540 N$$

$$(+) \rightarrow \sum F_x = 0$$

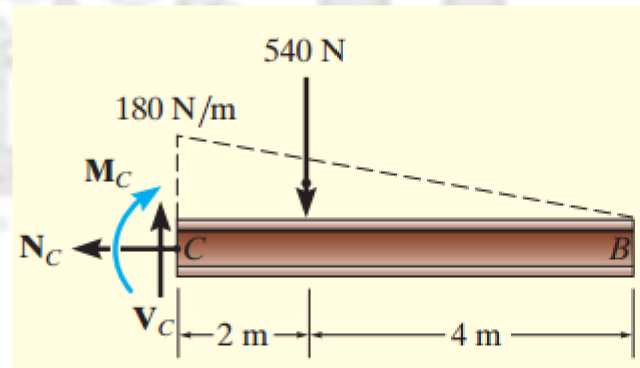
$$-N_c = 0$$

$$(+) \uparrow \sum F_y = 0$$

$$V_c - 540 = 0 \rightarrow V_c = 540 N$$

$$\circlearrowleft (+) \sum M_c = 0 \rightarrow -M_c - 540 \times 2 = 0$$

$$M_c = -1080 N.m$$

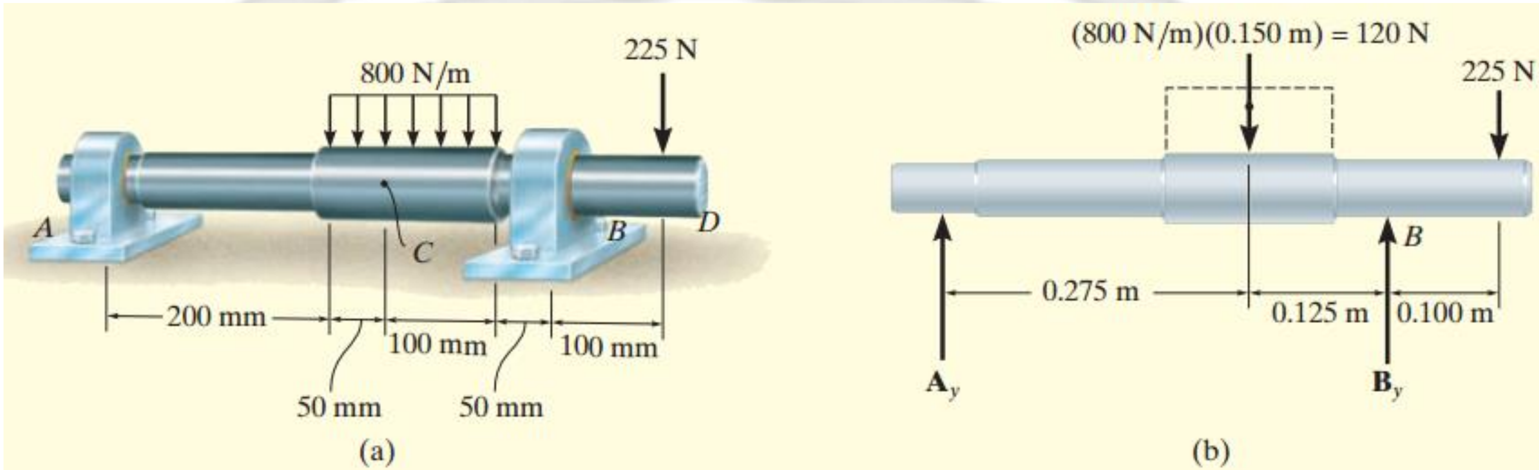


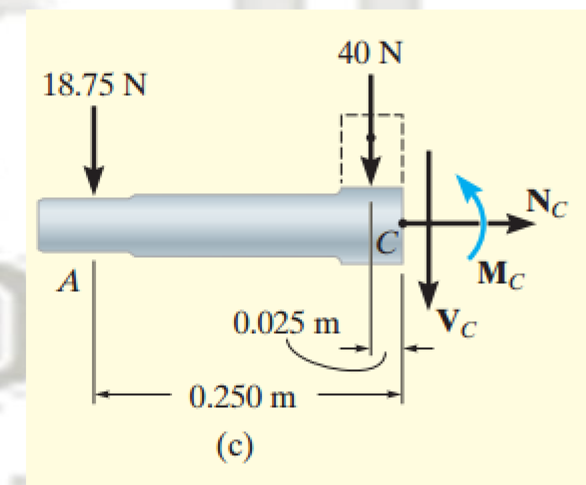
The negative sign indicates that acts in the opposite direction to that shown on the free-body diagram.

H.W. Try solving this problem using segment AC, by first obtaining the support reactions at A.

EXAMPLE 1-2

Determine the resultant internal loadings acting on the cross section at C of the machine shaft shown in the Figure. The shaft is supported by support bearings at A and B, which only give vertical forces on the shaft.





$$\circlearrowright(+)\sum M_B = 0 \rightarrow -A_y \times 0.4 + 120 \times 0.125 - 225 \times 0.1 = 0$$

$$A_y = -18.75N$$

$$(+)\rightarrow \sum F_x = 0 \rightarrow N_c = 0$$

$$(+)\uparrow \sum F_y = 0 \rightarrow -18.75 - 40 - Vc = 0$$

$$V_c = -58.8N$$

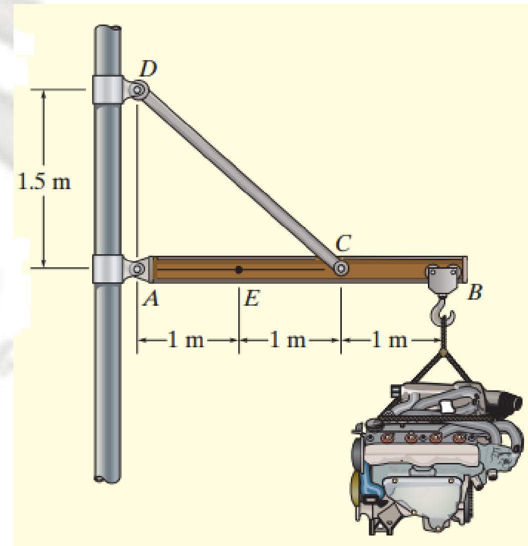
$$\circlearrowright(+)\sum M_c = 0 \rightarrow M_c + 40 \times 0.025 + 18.75 \times 0.25 = 0$$

$$M_c = -5.69N.m$$

H.W. Calculate the reaction at B and try to obtain the same results using segment CBD of the shaft.

EXAMPLE 1-3

The 500-kg engine is suspended from the crane boom in the Figure. Determine the resultant internal loadings acting on the cross section of the boom at point E.



$$\circlearrowright(+)\sum M_A = 0 \rightarrow F_{CD} \times \frac{3}{5} \times 2 - (500 \times 9.81) \times 3 = 0$$

$$F_{CD} = 12262.5N$$

$$(+) \rightarrow \sum F_x = 0 \rightarrow A_x - (12262.5 \times \frac{4}{5}) = 0$$

$$A_x = 9810N$$

$$(+) \uparrow \sum F_y = 0 \rightarrow -A_y + (12262.5 \times \frac{3}{5}) - (500 \times 9.81) = 0$$

$$A_y = 2452.5N$$

$$(+) \rightarrow \sum F_x = 0 \rightarrow N_E + 9810 = 0$$

$$N_E = -9810N = -9.81kN$$

$$+\uparrow \sum F_y = 0 \rightarrow -V_E - 2452.5N = 0$$

$$V_E = -2452.5N = -2.54kN$$

$$\circlearrowright(+)\sum M_E = 0 \rightarrow M_E + 2452.5 \times 1 = 0$$

$$M_E = -2452.5N.m = -2.45kN.m$$