Stress Analysis

Lecture 1

ME 276

Spring 2017-2018

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Course Materials

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COURSE OUTLINE

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- Fundamentals
  - Introduction - Mechanical Engineering Design
  - Load Analysis
  - Materials
  - Stresses and Strains
  - Theories of Failure

- Applications
  - Bolt Design
  - Power Screw Design
  - Shaft Design

Fundamentals

Introduction - Mechanical Engineering Design

Introduction - Mechanical Engineering Design

- Phases and Interactions of the Design Process
- Design Considerations.
- Design Tools and Resources.
- Standard and Codes.
- System of Units.
- Economics.
- Safety.

Load Analysis

Load Analysis

This course is concerned with the design and analysis of machine and structural components. Since these are load-carrying members, an analysis of loads is of fundamental importance. A sophisticated stress or deflection analysis is of little value if it is based on incorrect loads. A mechanical component cannot be satisfactory unless its design is based on realistic operating loads.

Load Analysis

Sometimes the service or operating loads can be readily determined, as are those on some engines, compressors, and electric generators that operate at known torques and speeds. Often the loads are difficult to determine, as are those on automotive chassis components (which depend on road surfaces and driving practices) or on the structure of an airplane (which depends on air turbulence and pilot decisions).

Load Analysis

Sometimes experimental methods are used to obtain a statistical definition of applied loads. In other instances engineers use records of service failures together with analyses of strength in order to infer reasonable estimates of loads encountered in service.
The determination of appropriate loads is often a difficult and challenging initial step in the design of a machine or structural component.

Load Analysis

- Equilibrium equation

For a nonaccelerating body

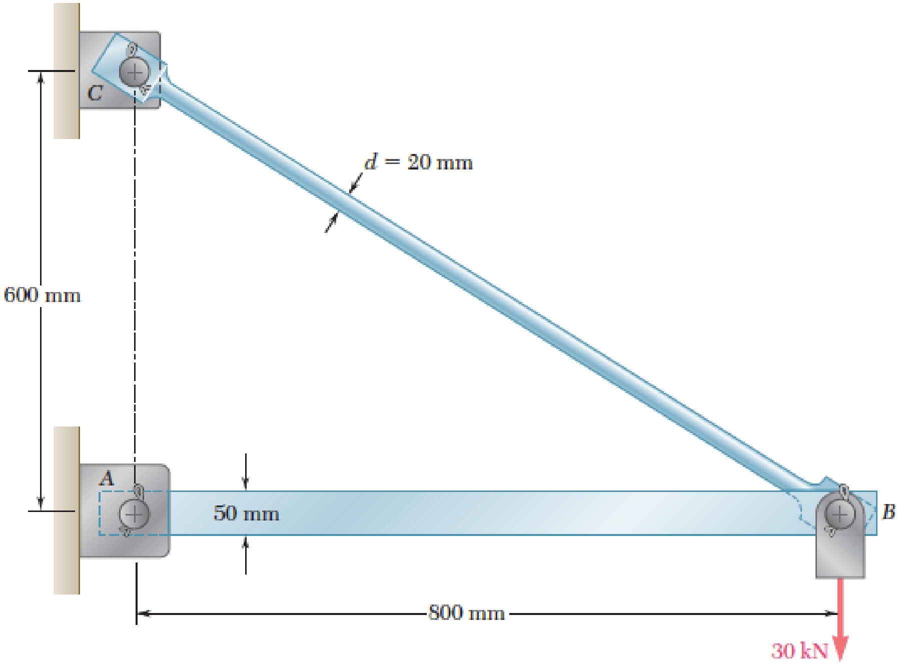
$$\sum F = 0 \quad \text{and} \quad \sum M = 0$$

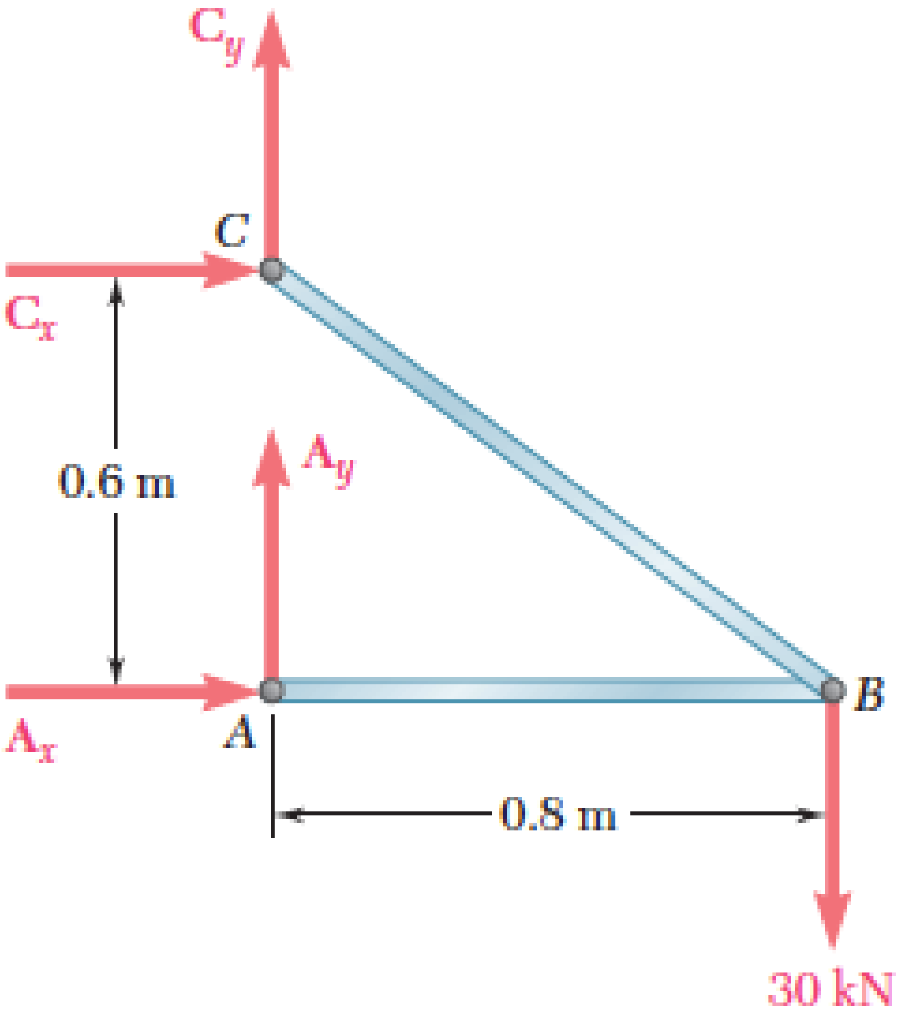
For a accelerating body

$$\sum F = ma \quad \text{and} \quad \sum M = I\alpha$$

Load Analysis

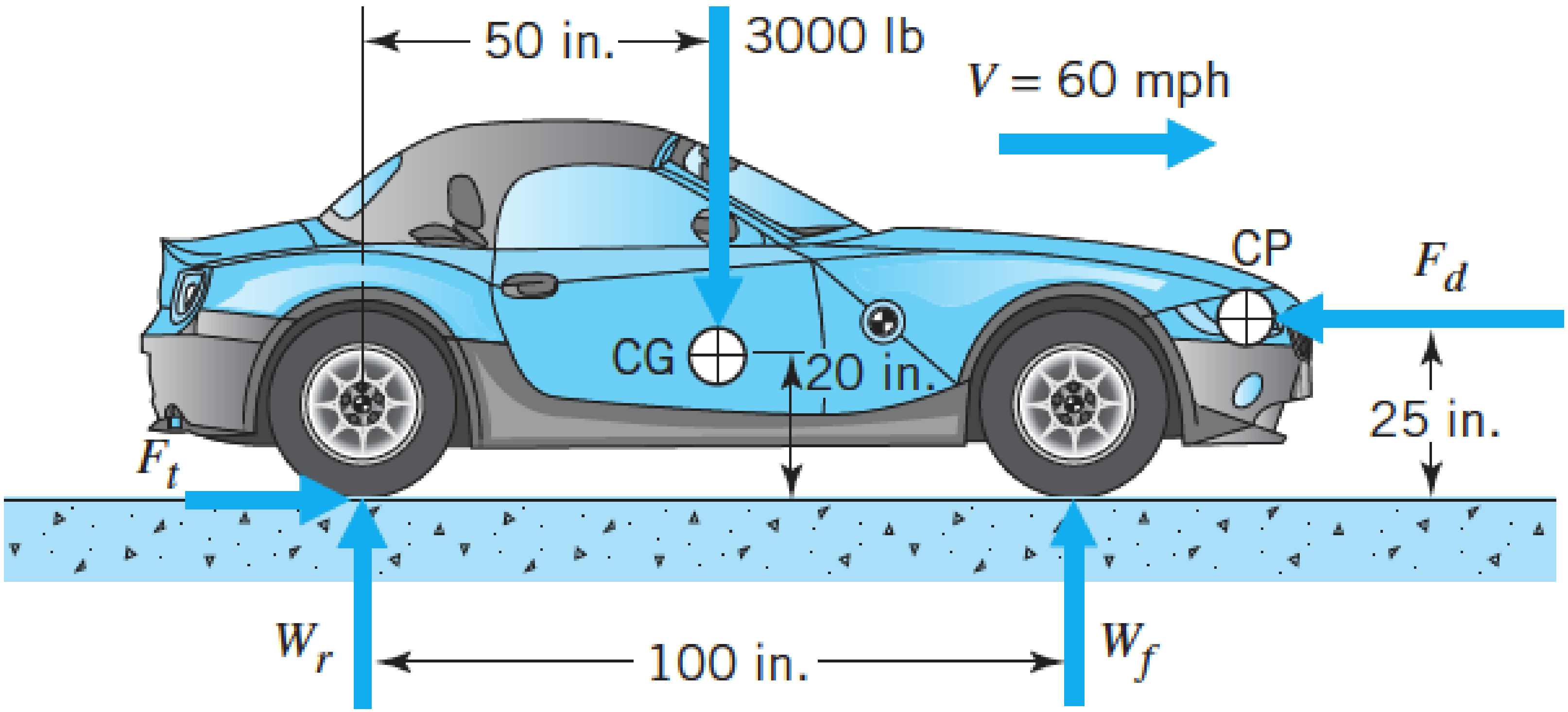
- Free Body Diagrams





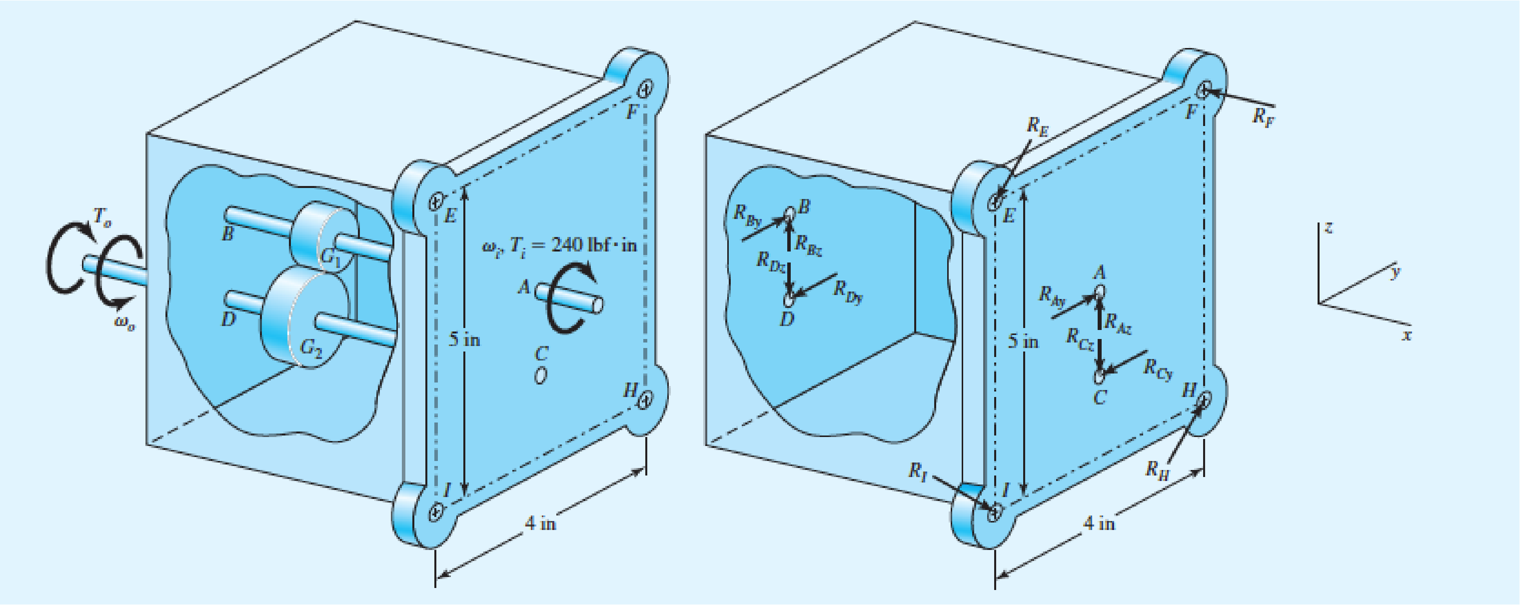
Load Analysis

- Free Body Diagrams



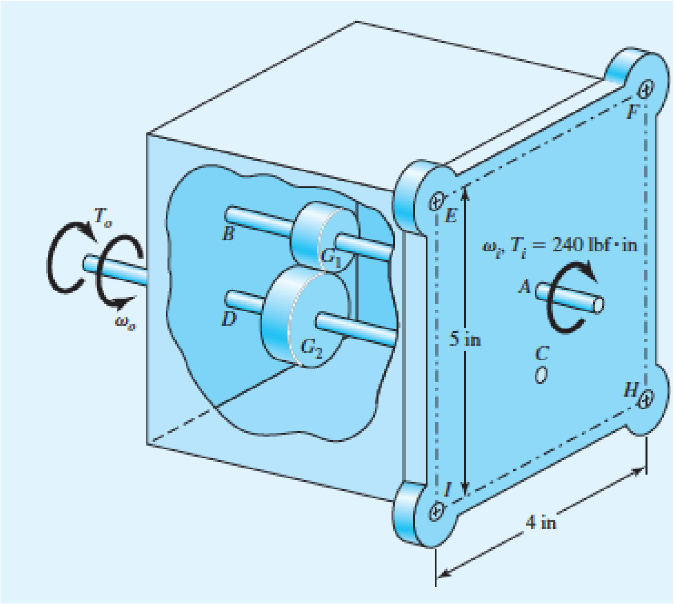
Load Analysis

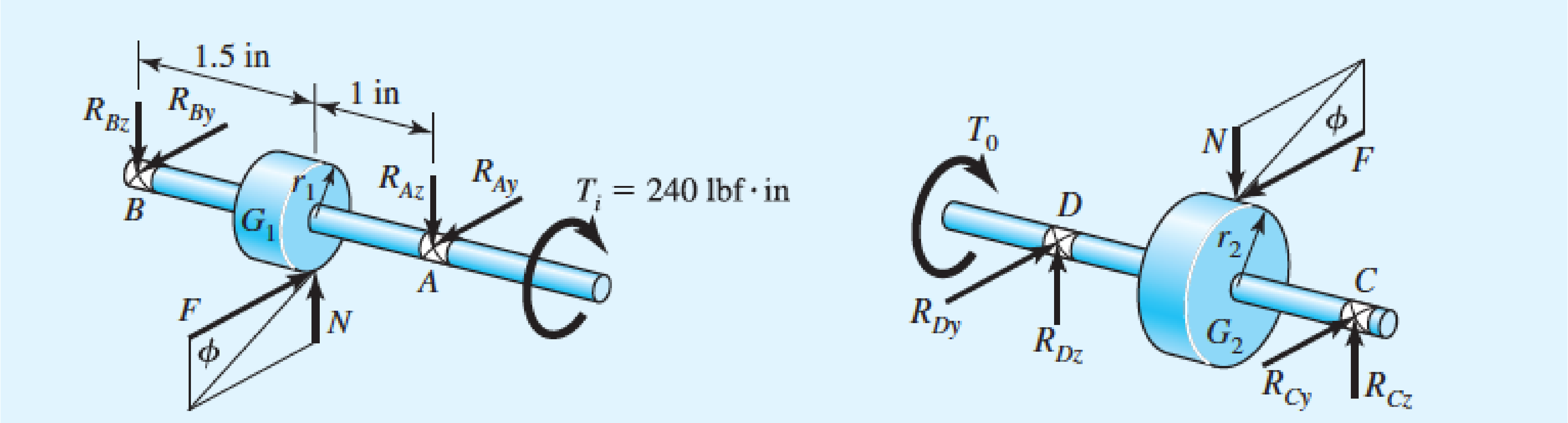
- Free Body Diagrams



Load Analysis

- Free Body Diagrams



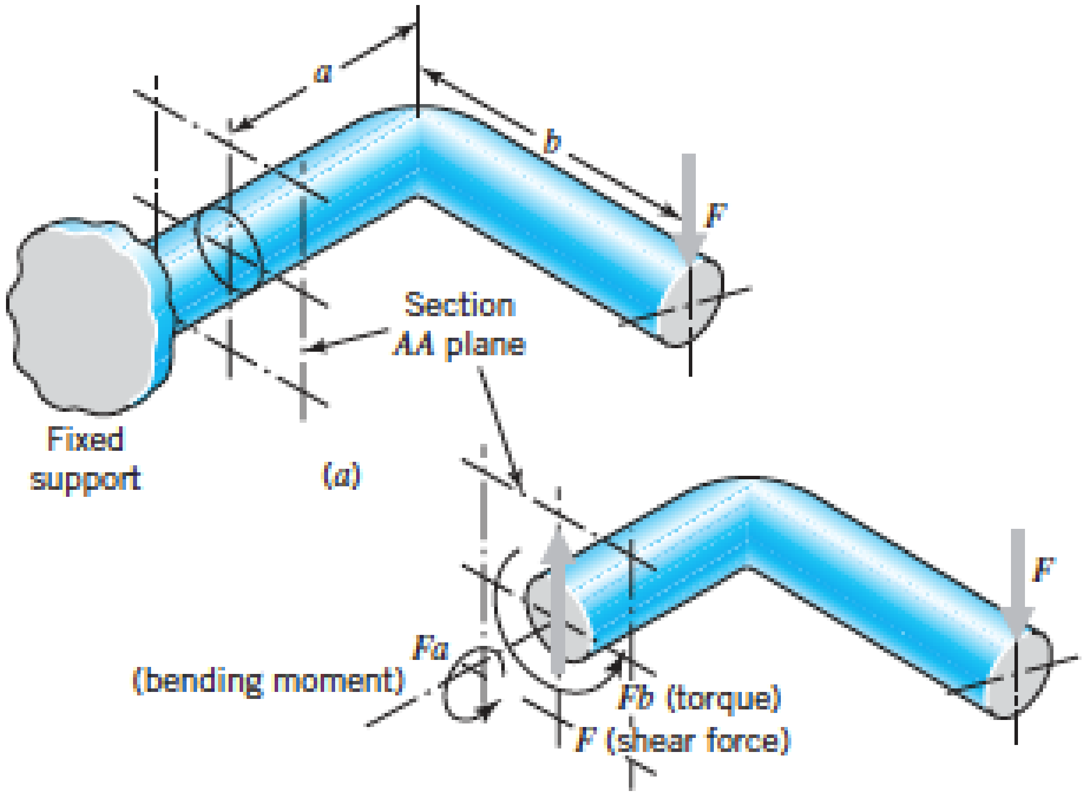


(*c*) Input shaft

(*d*) Output shaft

Load Analysis

- Determination of internal Loads



Materials

Materials

Material Selection

Family	Classes	Short Name
Metals (the metals and alloys of engineering)	Aluminum alloys	Al alloys
	Copper alloys	Cu alloys
	Lead alloys	Lead alloys
	Magnesium alloys	Mg alloys
	Nickel alloys	Ni alloys
	Carbon steels	Steels
	Stainless steels	Stainless steels
	Tin alloys	Tin alloys
	Titanium alloys	Ti alloys
	Tungsten alloys	W alloys
	Lead alloys	Pb alloys
	Zinc alloys	Zn alloys
Ceramics Technical ceramics (fine ceramics capable of load-bearing application)	Alumina	Al_2O_3
	Aluminum nitride	AlN
	Boron carbide	B_4C
	Silicon carbide	SiC
	Silicon nitride	Si_3N_4
	Tungsten carbide	WC
Nontechnical ceramics (porous ceramics of construction)	Brick	Brick
	Concrete	Concrete
	Stone	Stone
Glasses	Soda-lime glass	Soda-lime glass
	Borosilicate glass	Borosilicate glass
	Silica glass	Silica glass
	Glass ceramic	Glass ceramic
Polymers (the thermoplastics and thermosets of engineering)	Acrylonitrile butadiene styrene	ABS
	Cellulose polymers	CA
	Ionomers	Ionomers
	Epoxies	Epoxy
	Phenolics	Phenolics
	Polyamides (nylons)	PA
	Polycarbonate	PC

Materials

Material Selection

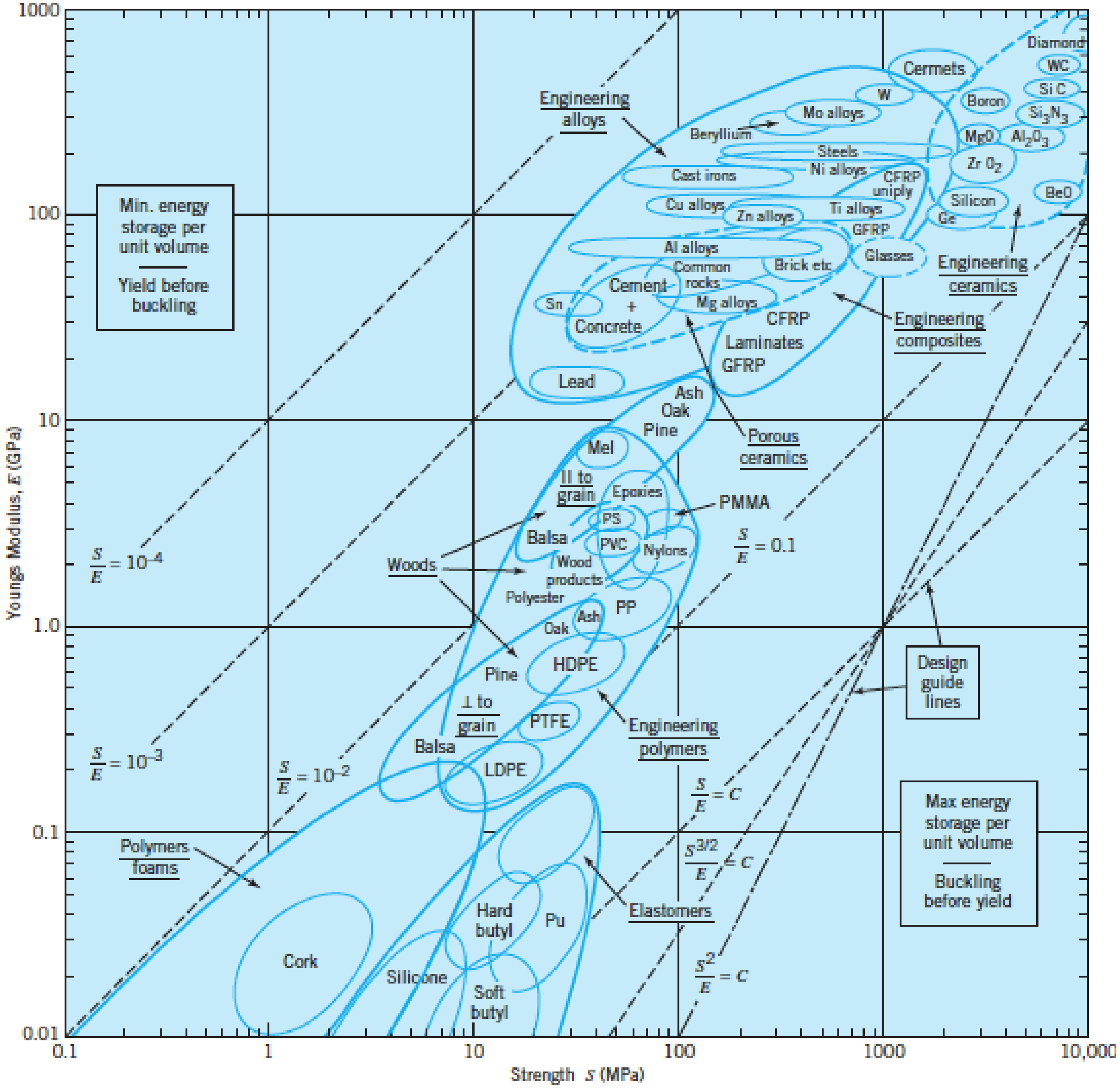
Family	Classes	Short Name
Polymers *(continued)*	Polyesters	Polyester
	Polyetheretherkeytone	PEEK
	Polyethylene	PE
	Polyethylene terephalate	PET or PETE
	Polymethylmethacrylate	PMMA
	Polyoxymethylene(Acetal)	POM
	Polypropylene	PP
	Polystyrene	PS
	Polytetrafluorethylene	PTFE
	Polyvinylchloride	PVC
Elastomers	Butyl rubber	Butyl rubber
(engineering rubbers,	EVA	EVA
natural and synthetic)	Isoprene	Isoprene
	Natural rubber	Natural rubber
	Polychloroprene (Neoprene)	Neoprene
	Polyurethane	PU
	Silicon elastomers	Silicones
Hybrids	Carbon-fiber reinforced polymers	CFRP
Composites	Glass-fiber reinforced polymers	GFRP
	SiC reinforced aluminum	Al-SiC
Foams	Flexible polymer foams	Flexible foams
	Rigid polymer foams	Rigid foams
Natural materials	Cork	Cork
	Bamboo	Bamboo
	Wood	Wood

From M. F. Ashby, *Materials Selection in Mechanical Design*, 3rd ed., Elsevier Butterworth-Heinemann, Oxford, 2005. Table 4–1, pp. 49–50.

Materials

Material Selection

- Strength



Materials

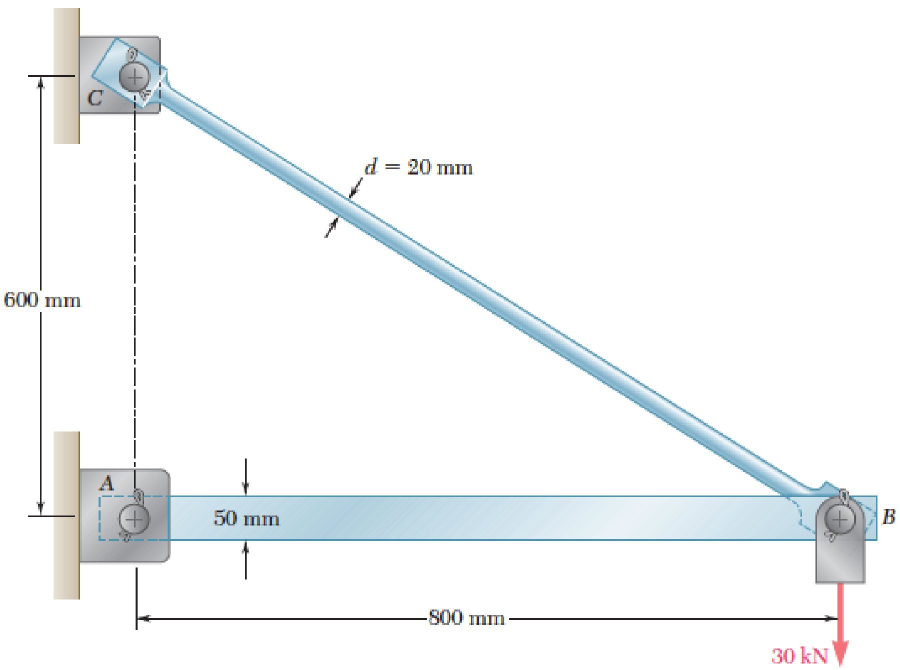
Material Selection Factors

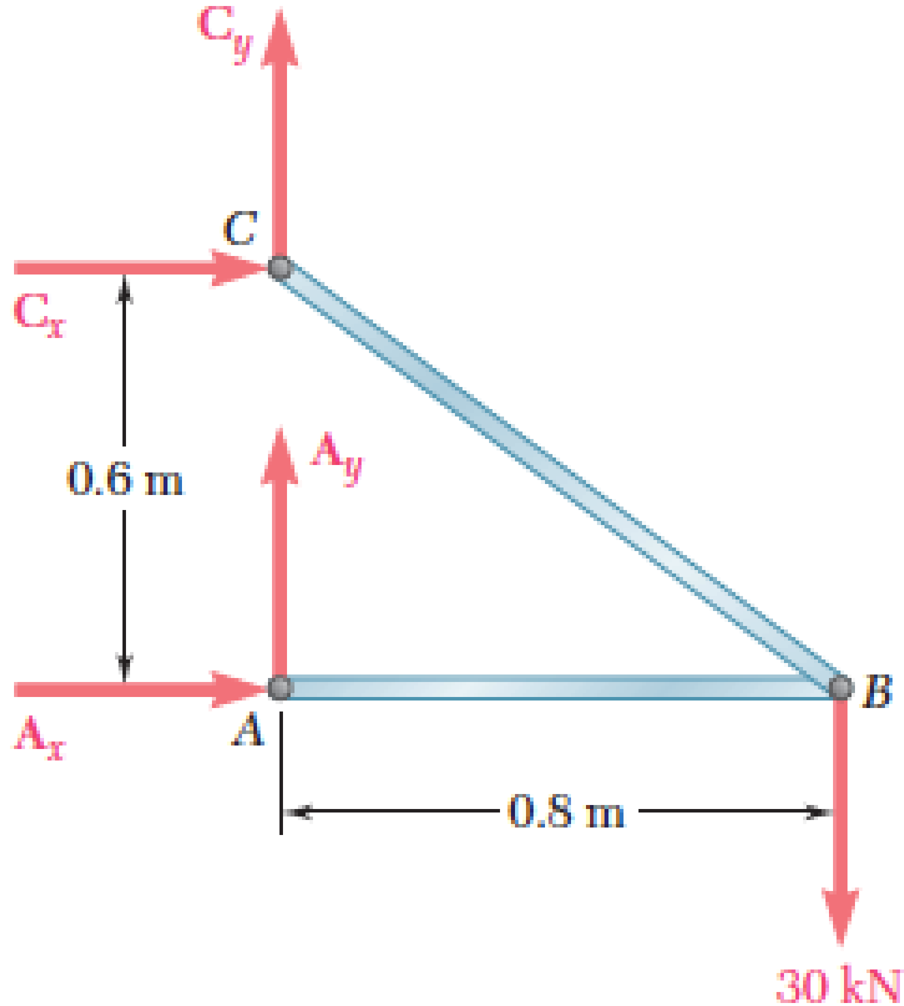
1. Availability
2. Cost
3. Material properties—mechanical, physical, chemical, dimensional
4. Manufacturing processes—machining, formability, joinability, finishing and coatings

Stresses and Strains

Stresses and Strains

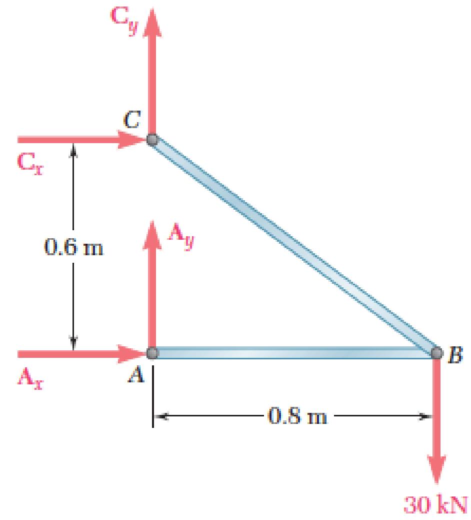
- Free Body Diagrams





Stresses and Strains

- Free Body Diagrams



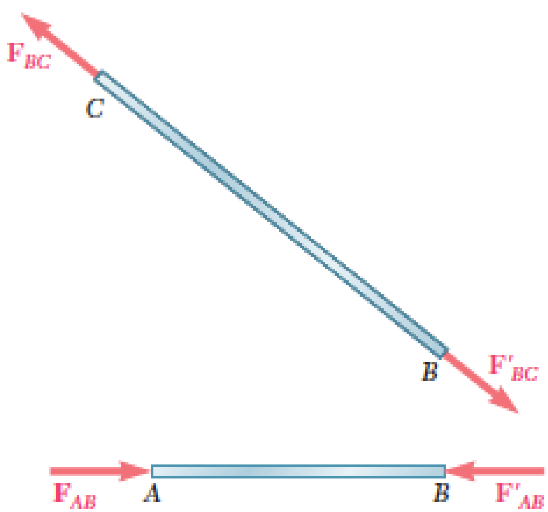


Fig. 1.5 Free-body diagrams of two-force members *AB* and *BC*.

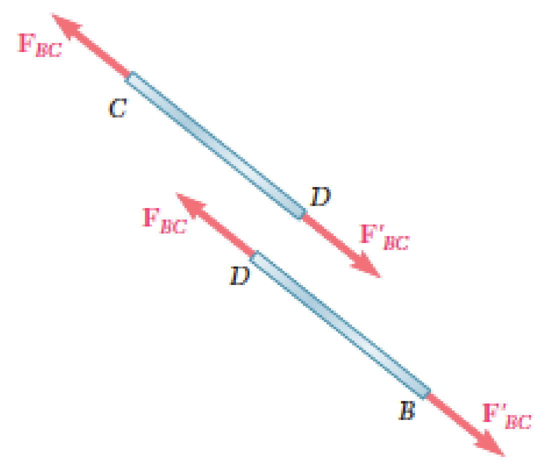


Fig. 1.6 Free-body diagrams of sections of rod *BC*.

Stresses and Strains

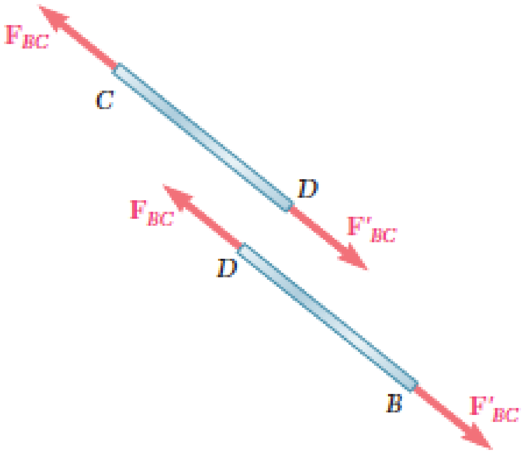


Fig. 1.6 Free-body diagrams of sections of rod *BC*.

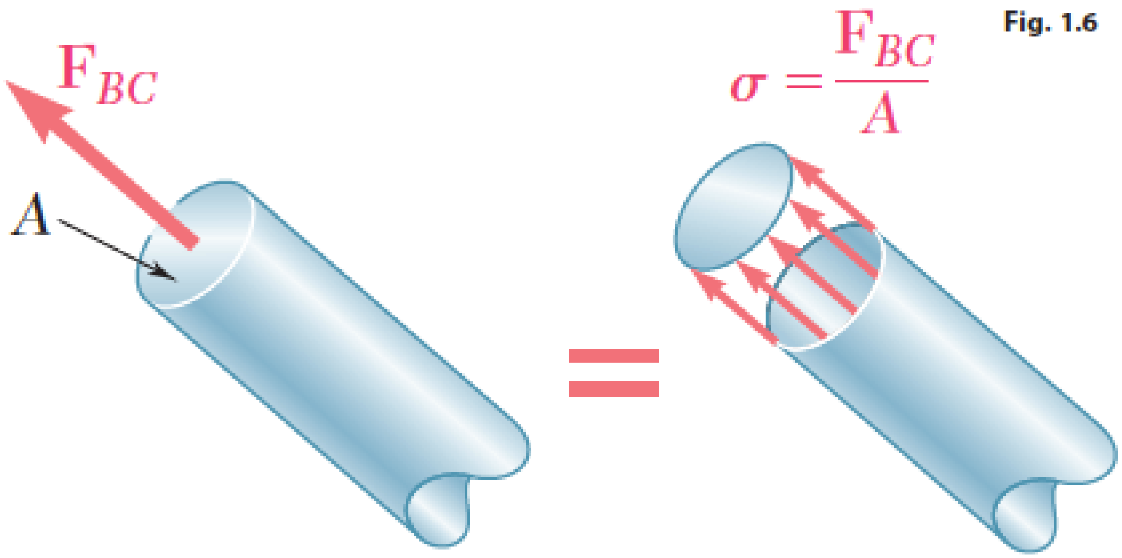
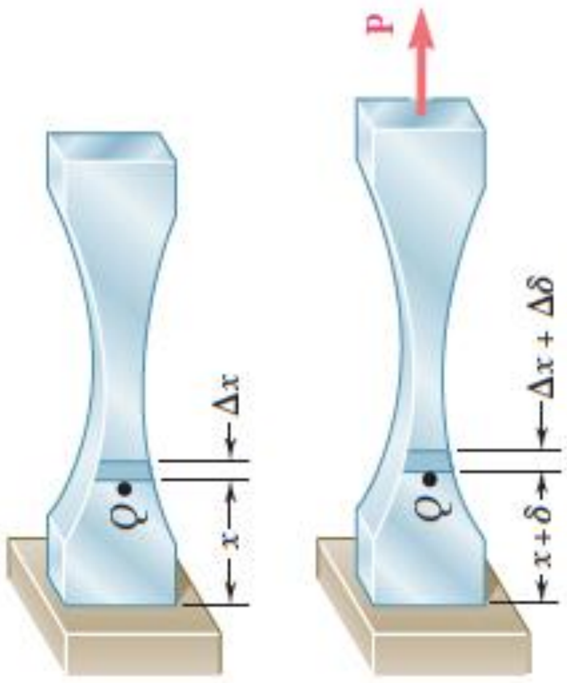


Fig. 1.7 Axial force represents the resultant of distributed elementary forces.

Stresses and Strains



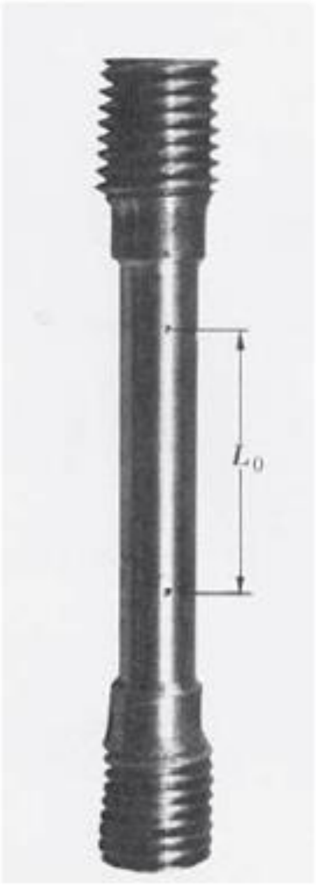


Photo 2.1 Typical tensile-test specimen. Undeformed gage length is L_0.

Stresses and Strains

Photo 2.2 Universal test machine used to test tensile specimens.

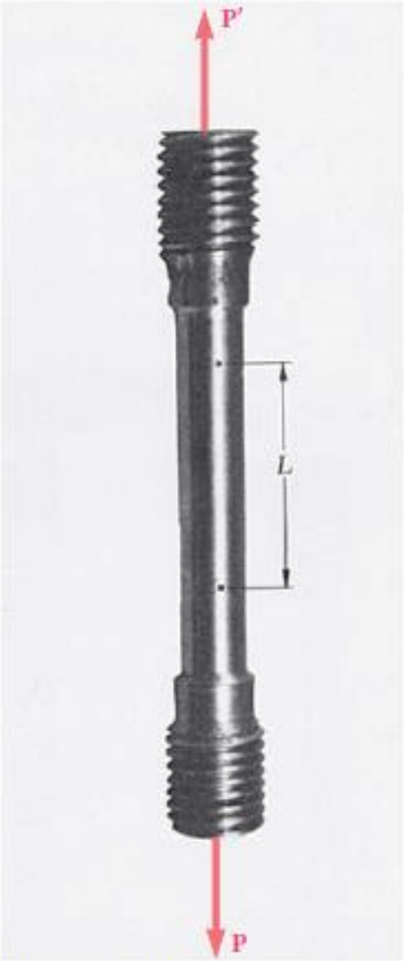
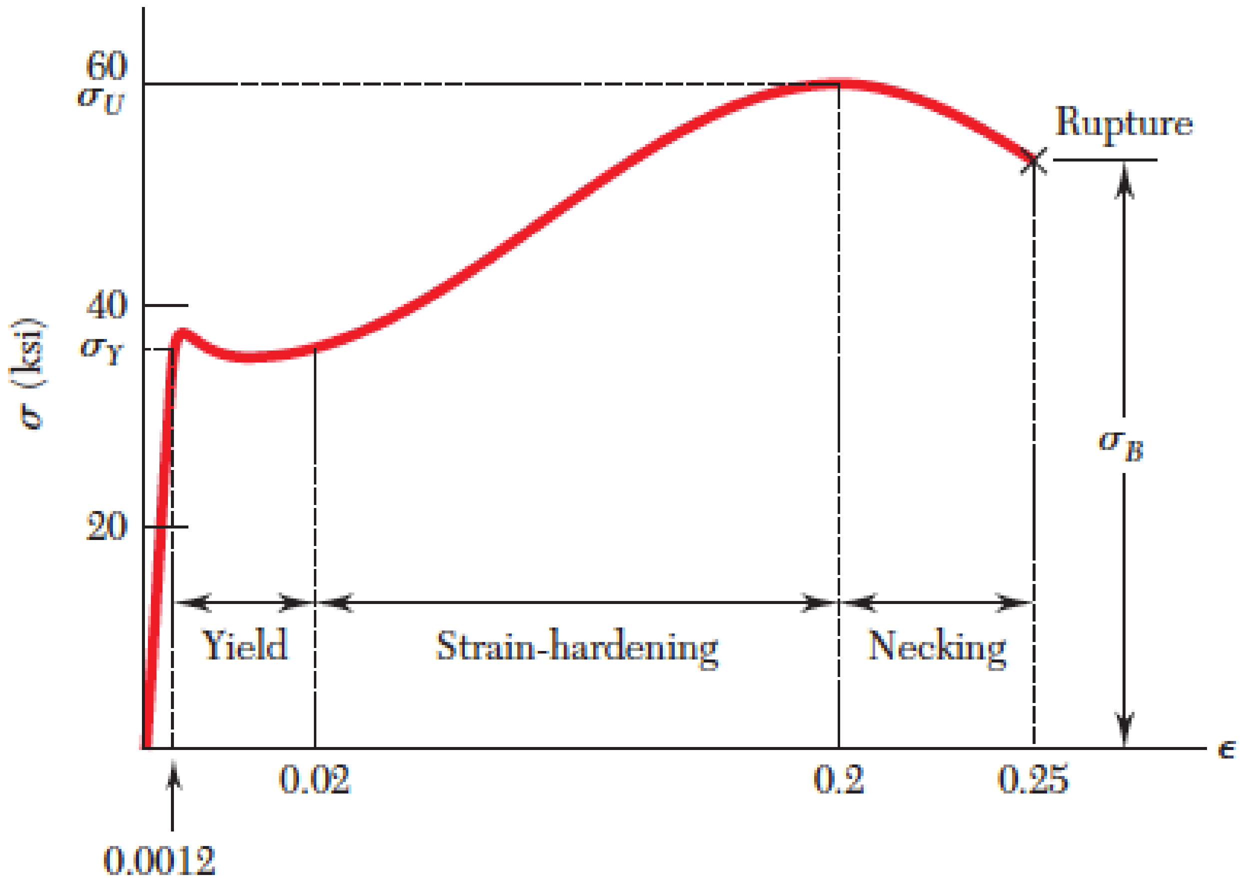


Photo 2.3 Elongated tensile test specimen having load P and deformed length $L > L_0$.

Stresses and Strains



(*a*) Low-carbon steel

Fig. 2.6 Stress-strain diagrams of two typical ductile materials.

Stresses and Strains

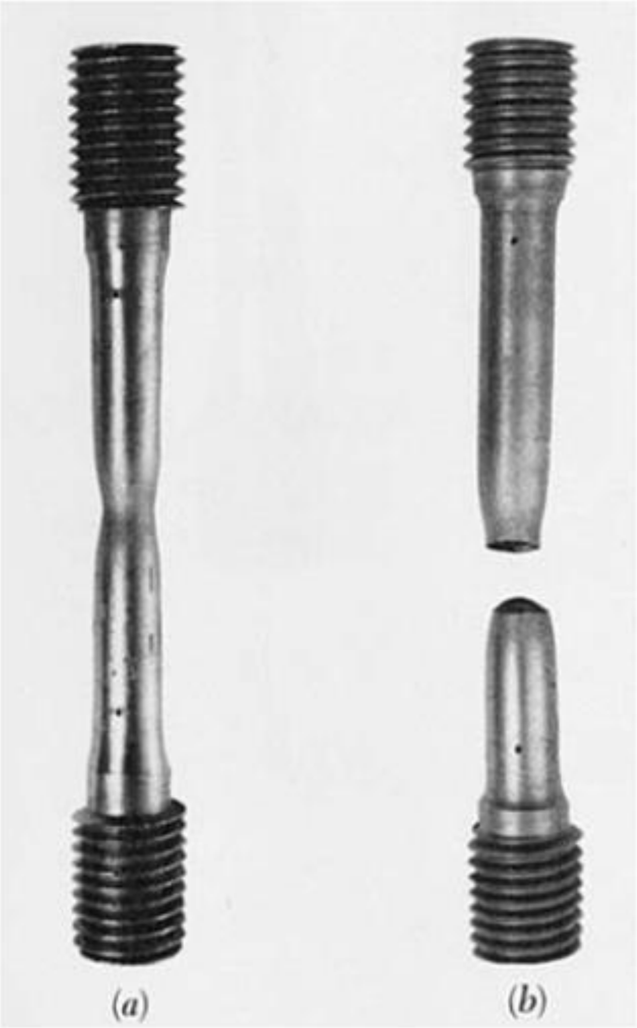


Photo 2.4 Ductile material tested specimens: (a) with cross-section necking, (b) ruptured.

Stresses

1. Axial Load

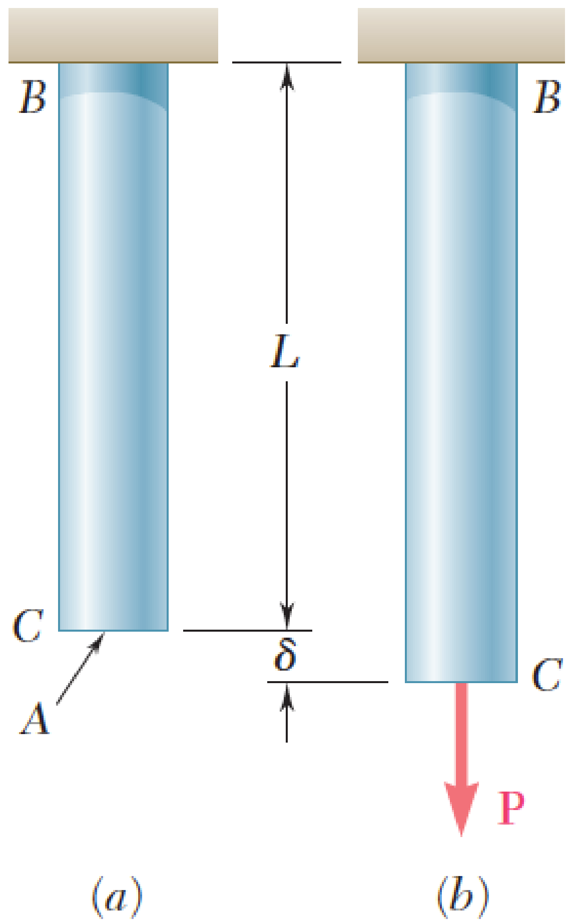


Fig. 2.1 Undeformed and deformed axially-loaded rod.

Stresses

1. Axial Load

Stresses

2. Torsion Load

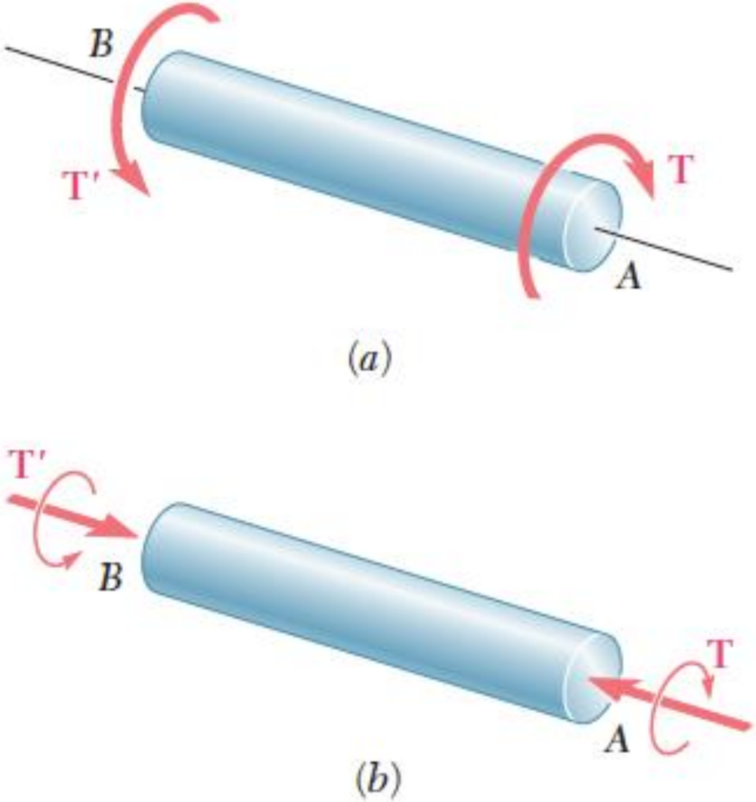


Fig. 3.1 Two equivalent ways to represent a torque in a free-body diagram.

Stresses

2. Torsion Load

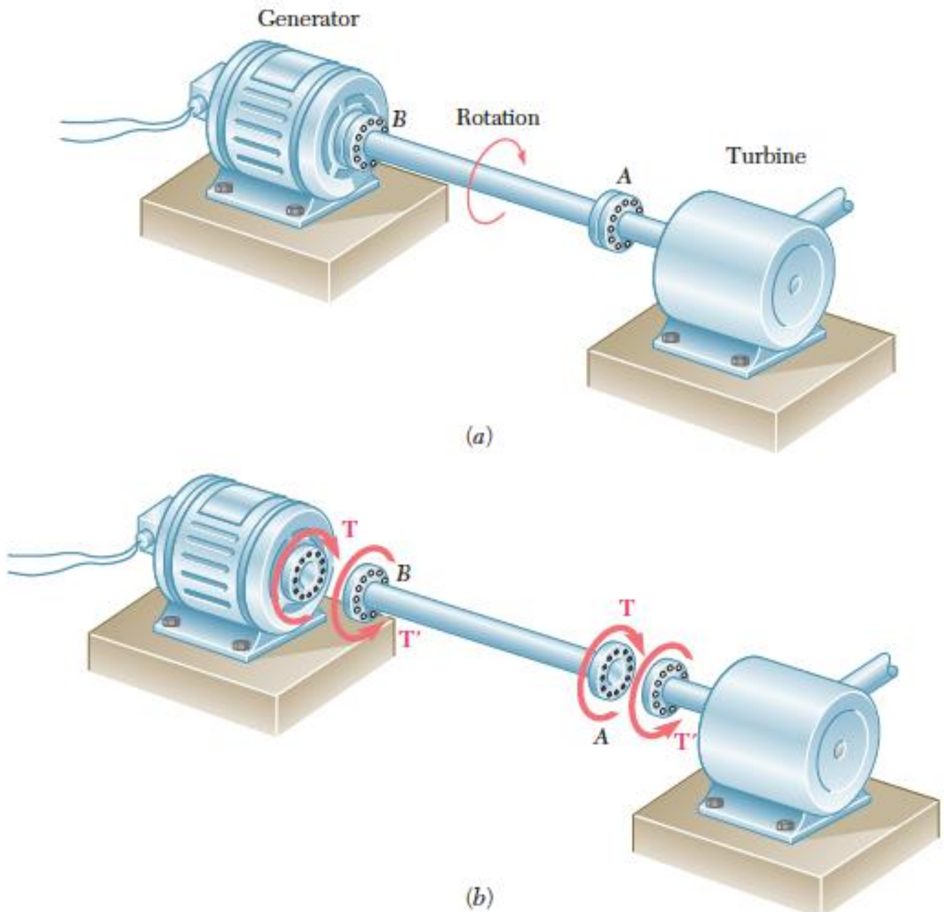


Fig. 3.2 (*a*) A generator receives power at a constant number of revolutions per minute from a turbine through shaft *AB*. (*b*) Free-body diagram of shaft *AB* along with the driving and reacting torques on the generator and turbine, respectively.

Stresses

2. Torsion Load

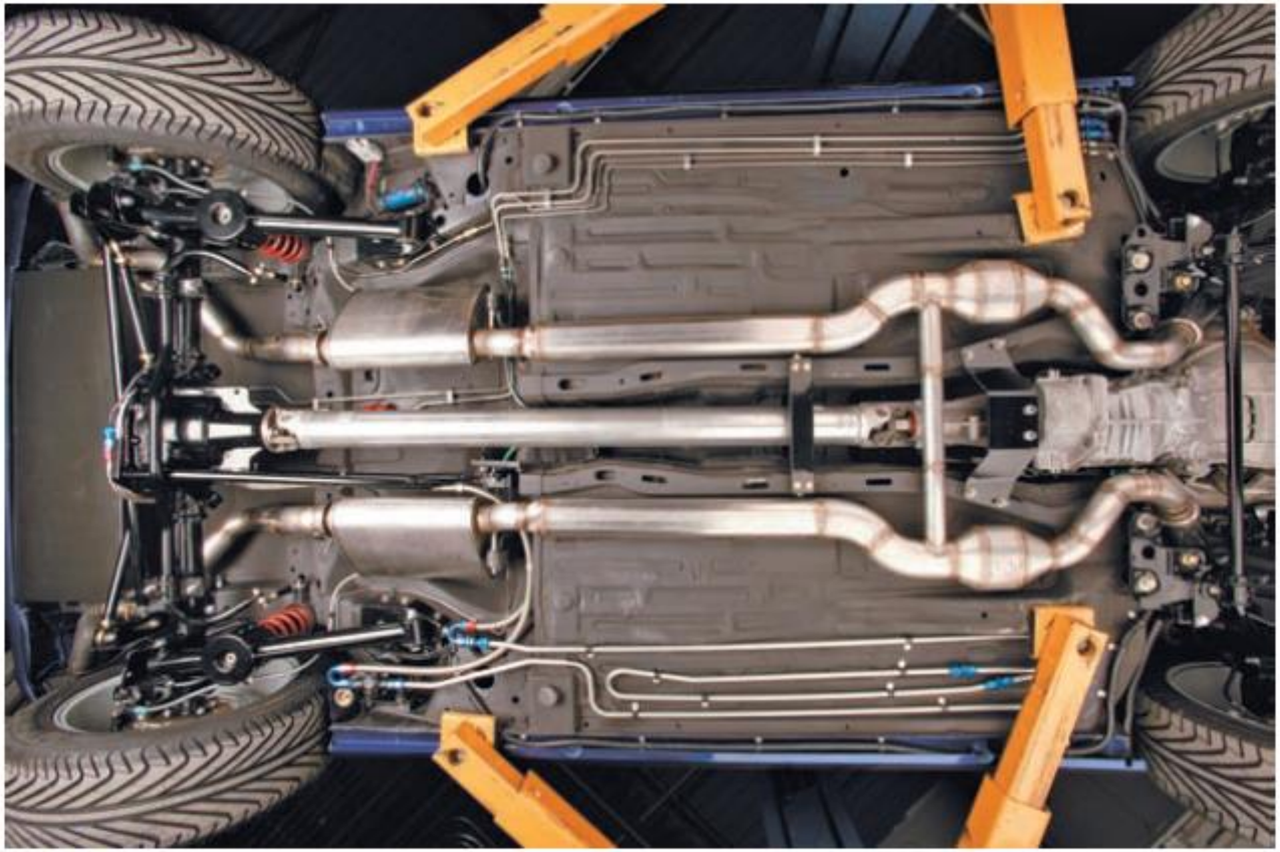


Photo 3.1 In this automotive power train, the shaft transmits power from the engine to the rear wheels.

Stresses

3. Bending Load

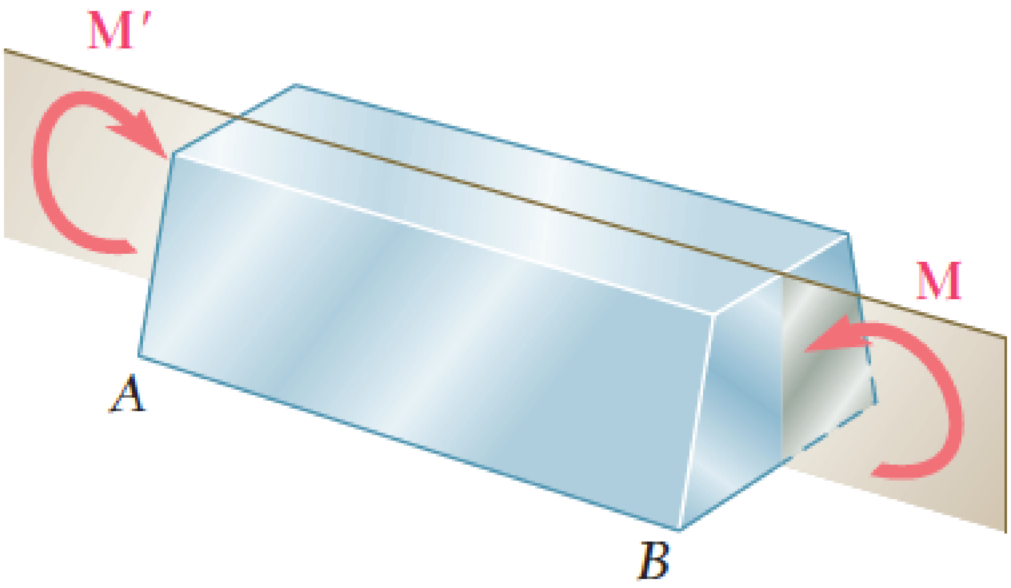
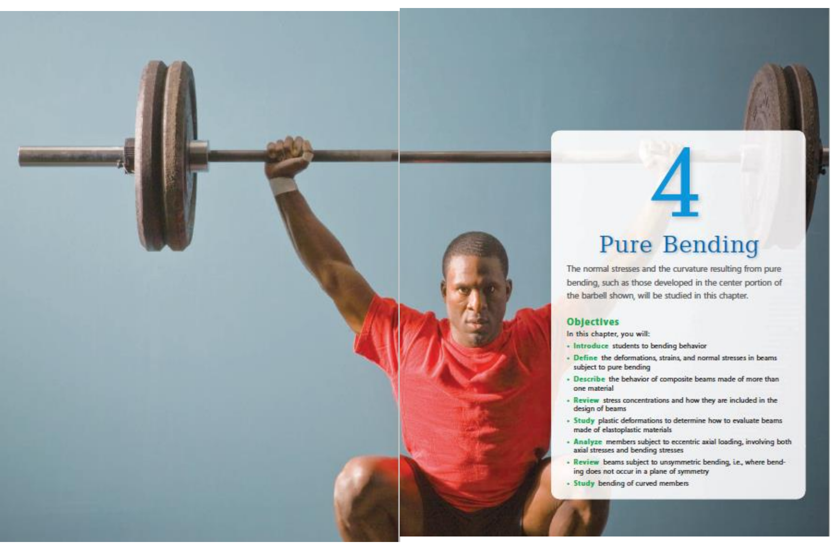


Fig. 4.1 Member in pure bending

Stresses

3. Bending Load



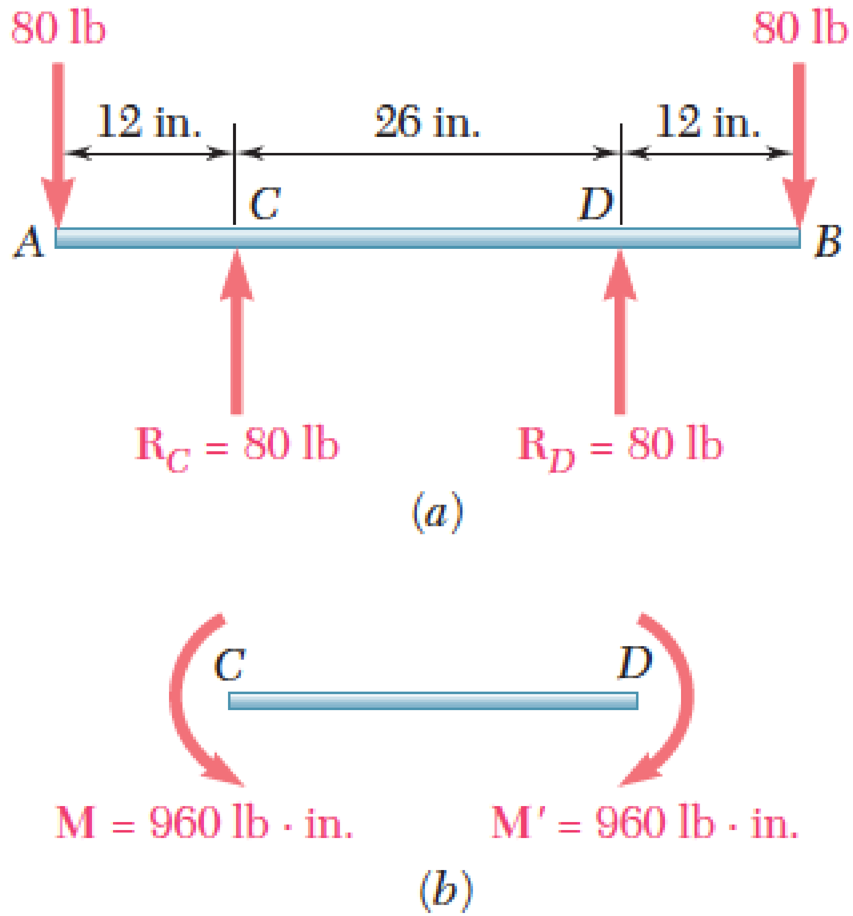


Fig. 4.2 (*a*) Free-body diagram of the barbell pictured in the chapter opening photo and (*b*) free-body diagram of the center portion of the bar, which is in pure bending.

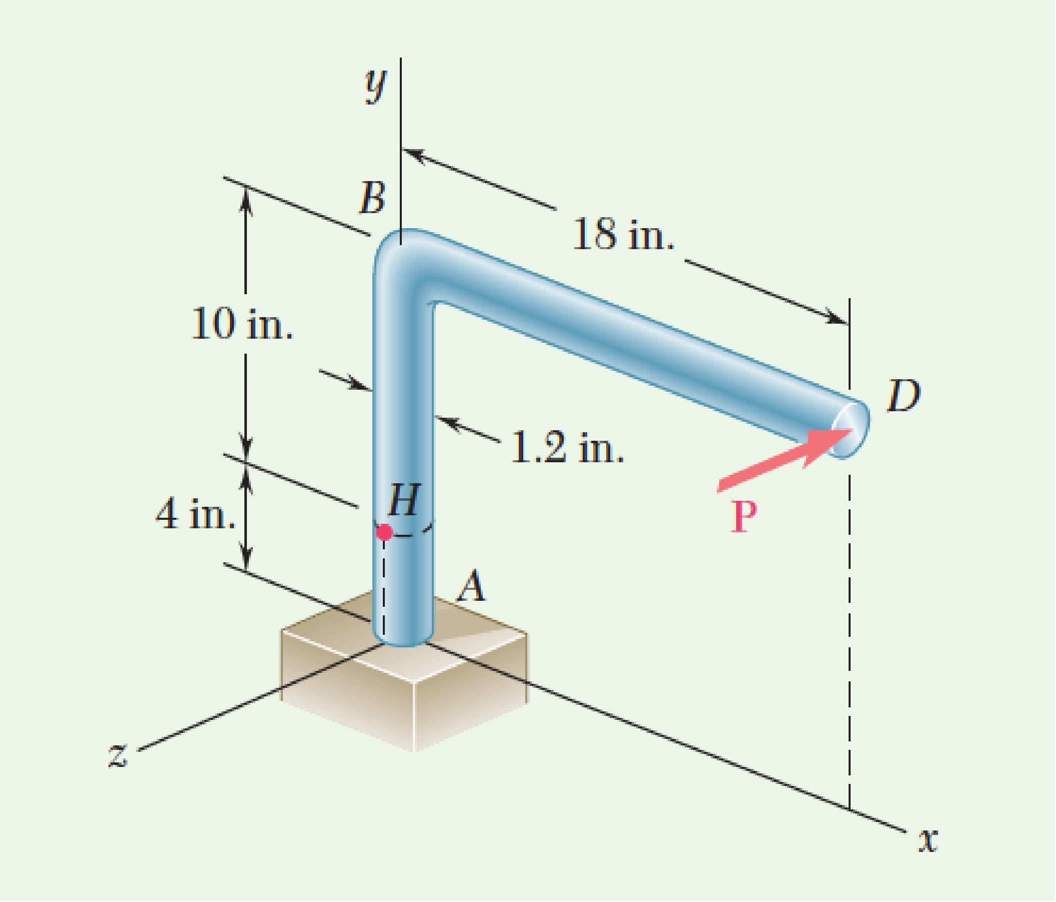
Stresses

3. Bending Load

Photo 4.1 The center portion of the rear axle of the sport buggy is in pure bending.

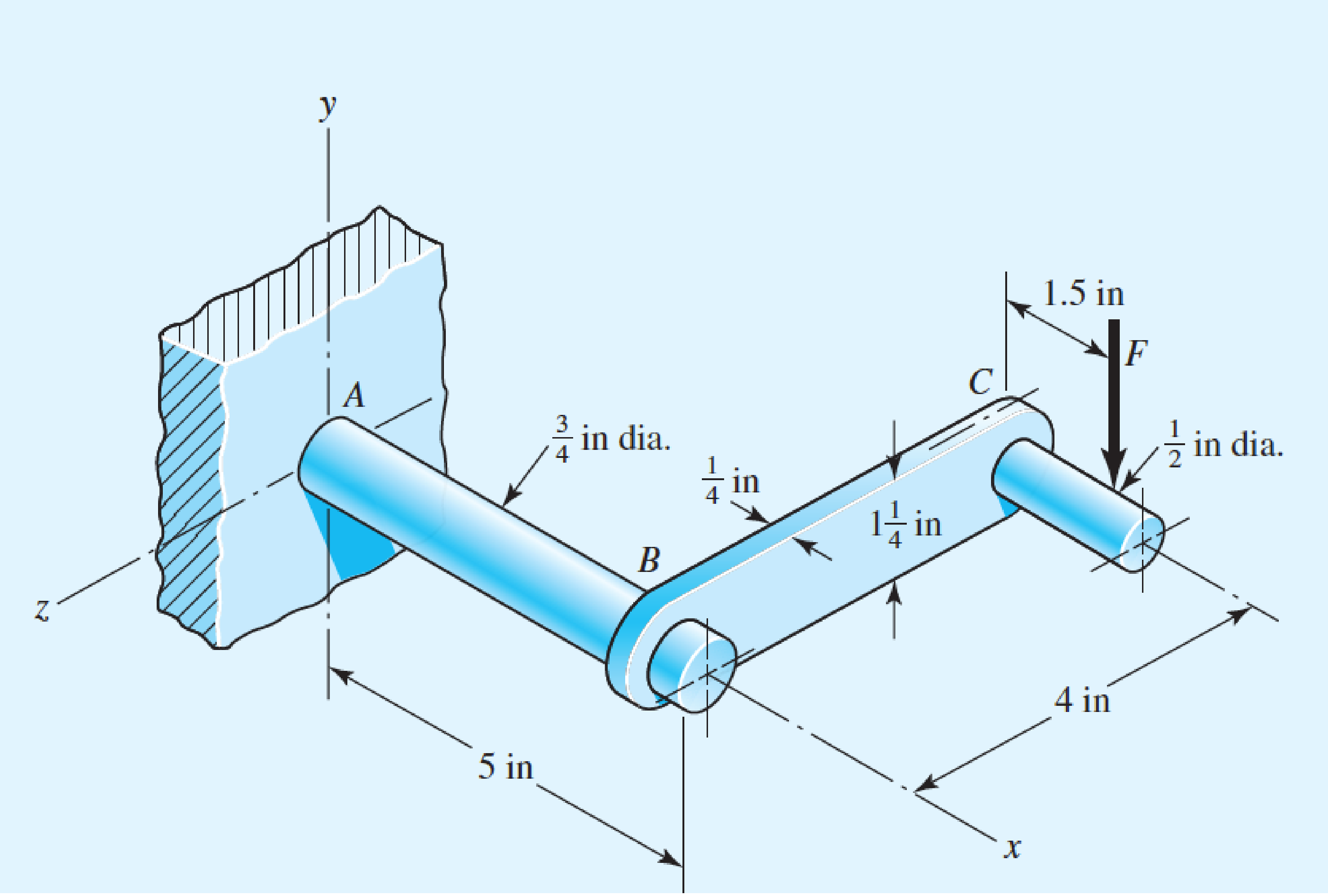
Stresses

4. Combined Loading

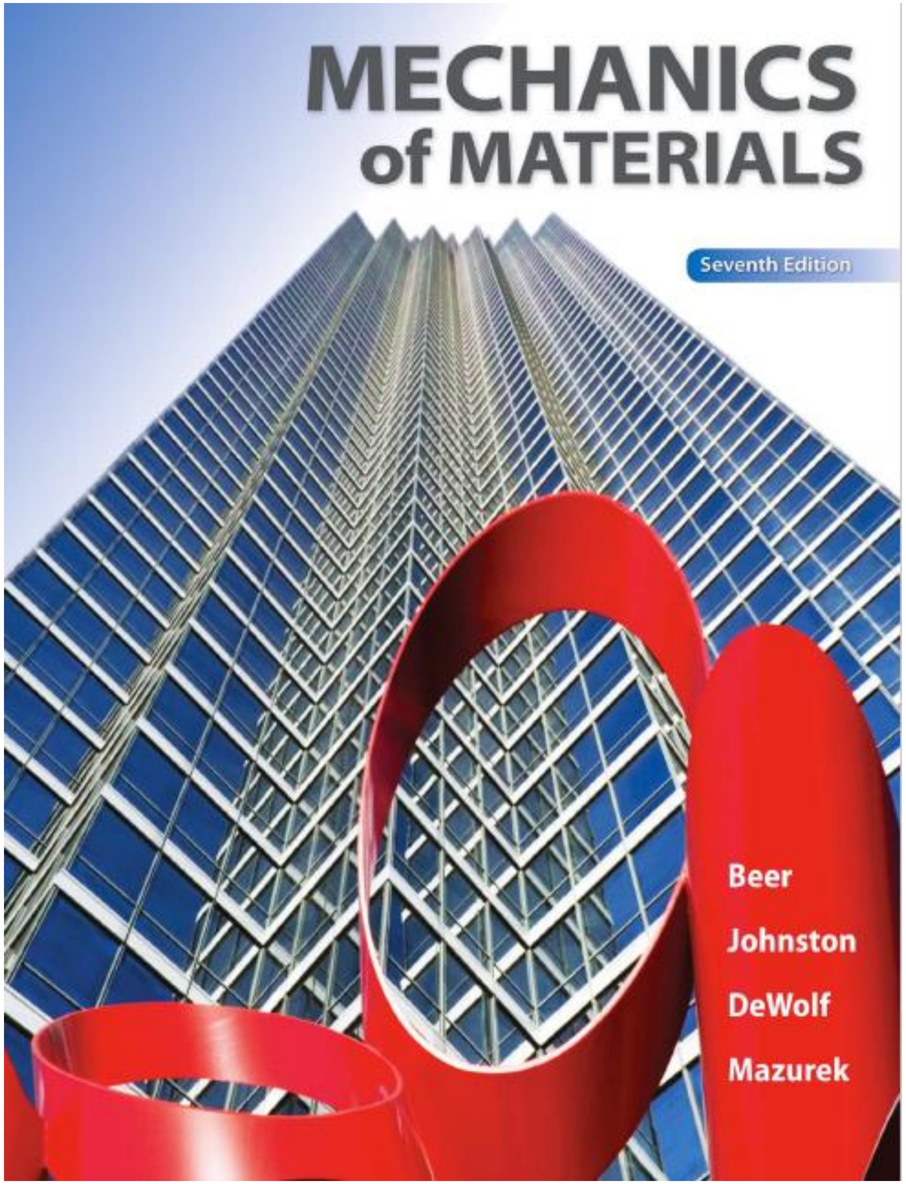


Stresses

4. Combined Loading



References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