Chapter 1:

Tension, Compression, and Shear

CENGAGE
Learning

Fig. 1-1

Plane frame structure

Fig. 1-2

Wind on sign

Fig. 1-3

(a) Overall FBD of plane frame structure from Fig. 1-1, and (b) Separate free-body diagrams of parts A through E and DF of the plane frame structure in Fig. 1-1

(a)

(b)
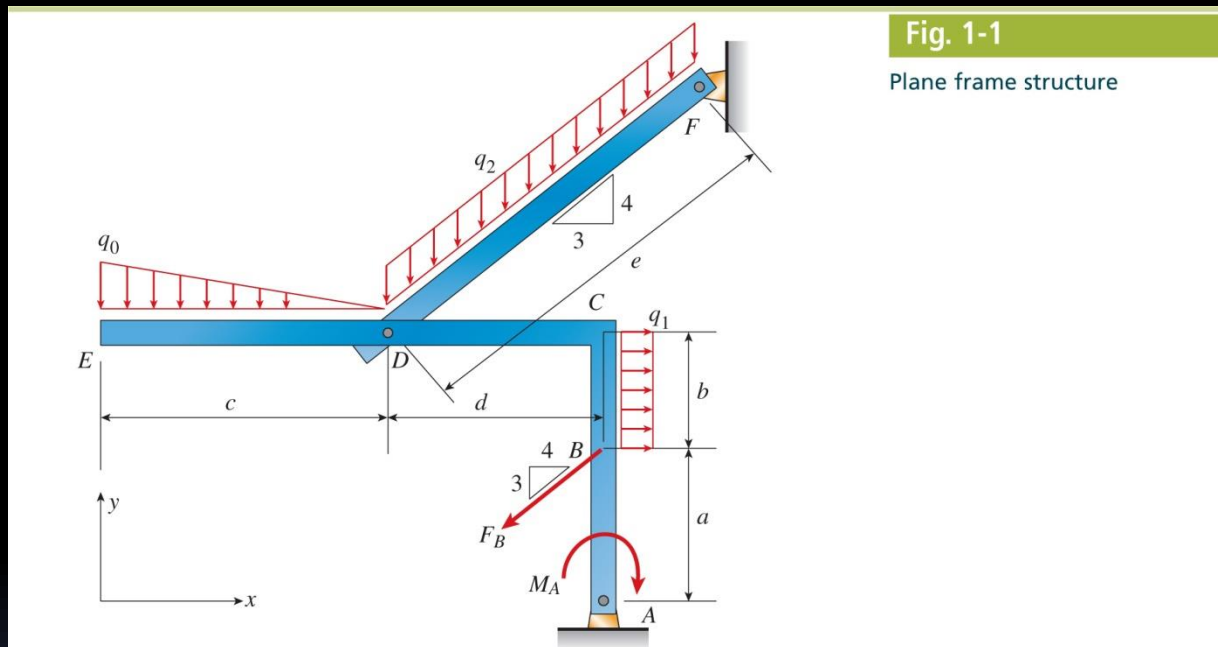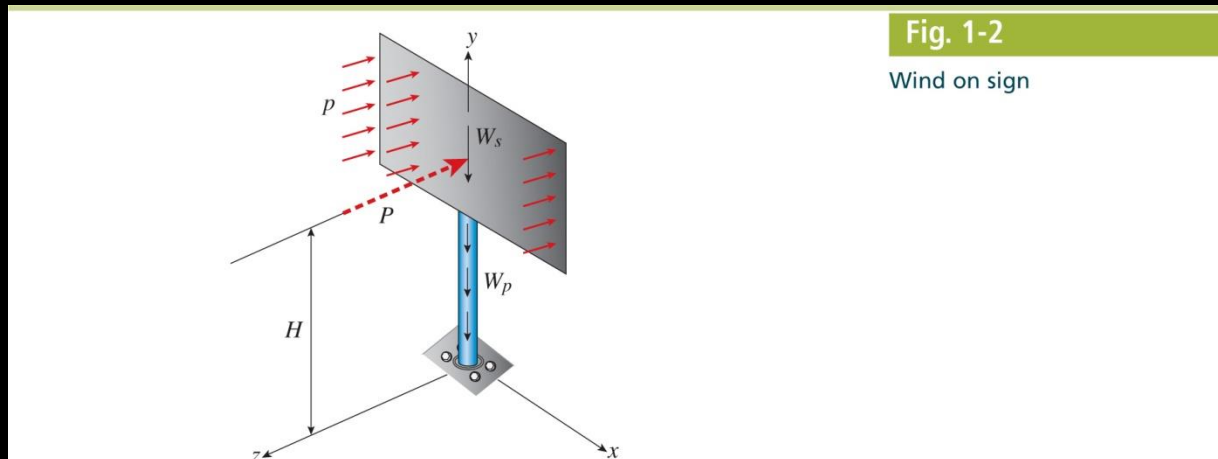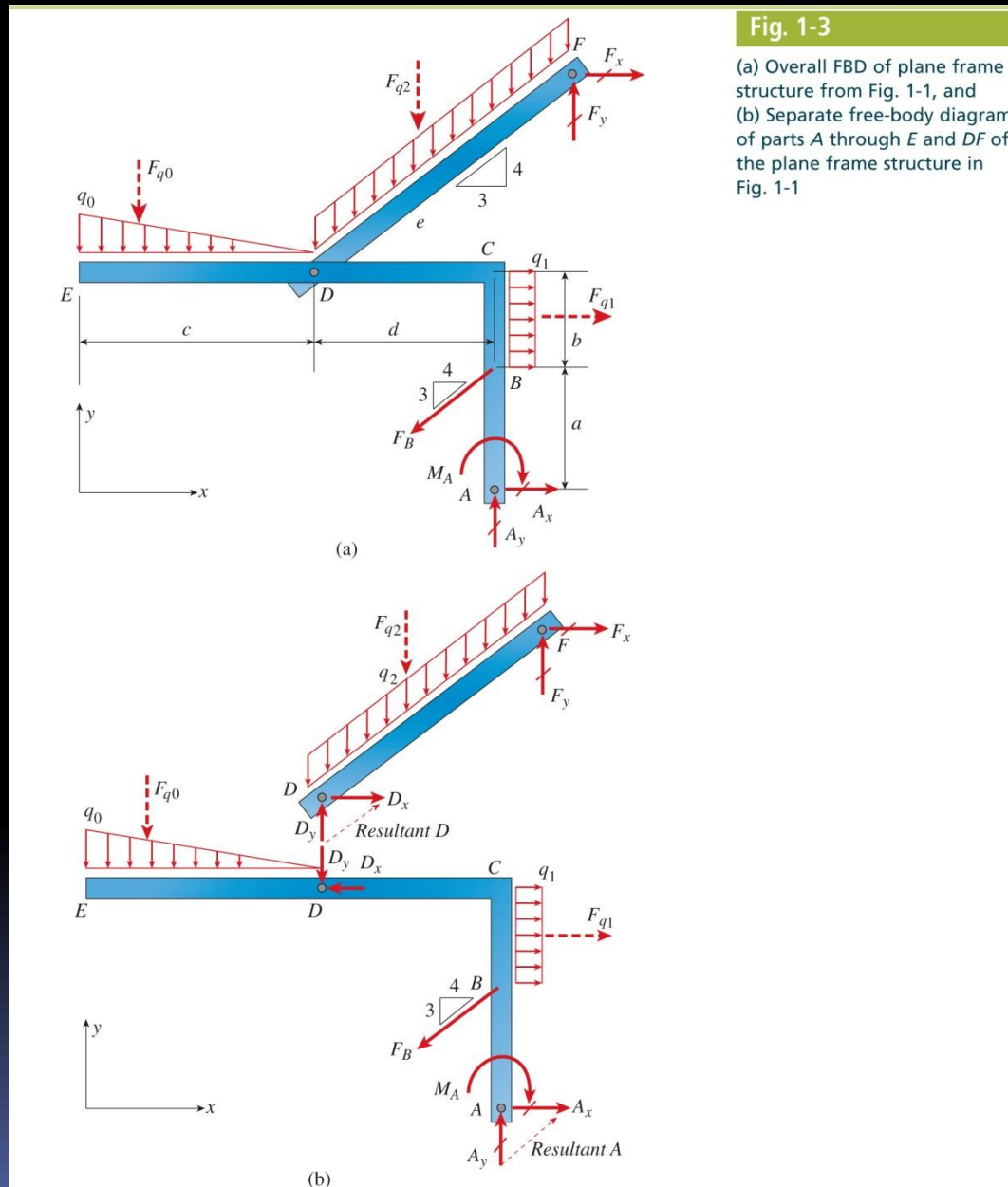
Table 1-1

Reaction and Connection Forces in 2D or 3D Static Analysis

Table 1-1 (continued)

(3) Sliding support

Frictionless sleeve on vertical shaft

(4) Clamped or fixed support

Weld

Base plate
Pole
Concrete pier
Fixed support at base of sign post (see Fig. 1-2)

(a) Two-dimensional fixed support

(b) Three-dimensional fixed support
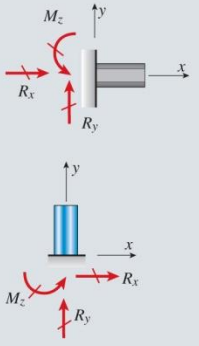
(5) Elastic or spring supports

(a) Translational spring (k)

Table 1-1 (continued)

(b) Rotational spring (k_r)
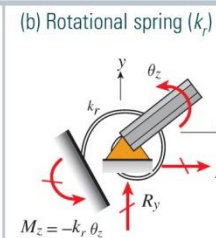
$M_z = -k_r\,\theta_z$

(6) Pinned connection (from Figs. 1-1 and 1-3)

Pin connection on old bridge (© Barry Goodno)
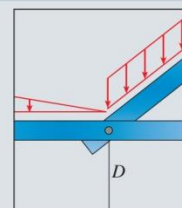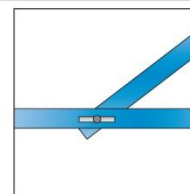
Pinned connection at D between members EDC and DF in plane frame (Fig. 1-1)
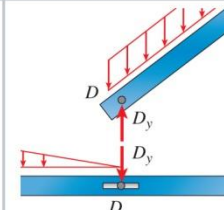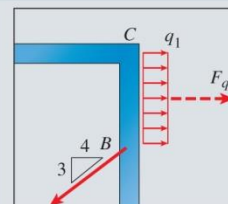
(7) Slotted connection *(modified connection from that shown in Figs.* 1-1 *and* 1-3*)*

Alternate slotted connection at D on plane frame (Note that the plane frame in Fig. 1-1 is *unstable* if this slotted connection is used instead of a pin at D.)

(8) Rigid connection *(internal forces and moment in members joined at C of plane frame in Fig. 1-1)*

Rigid connection at C on plane frame
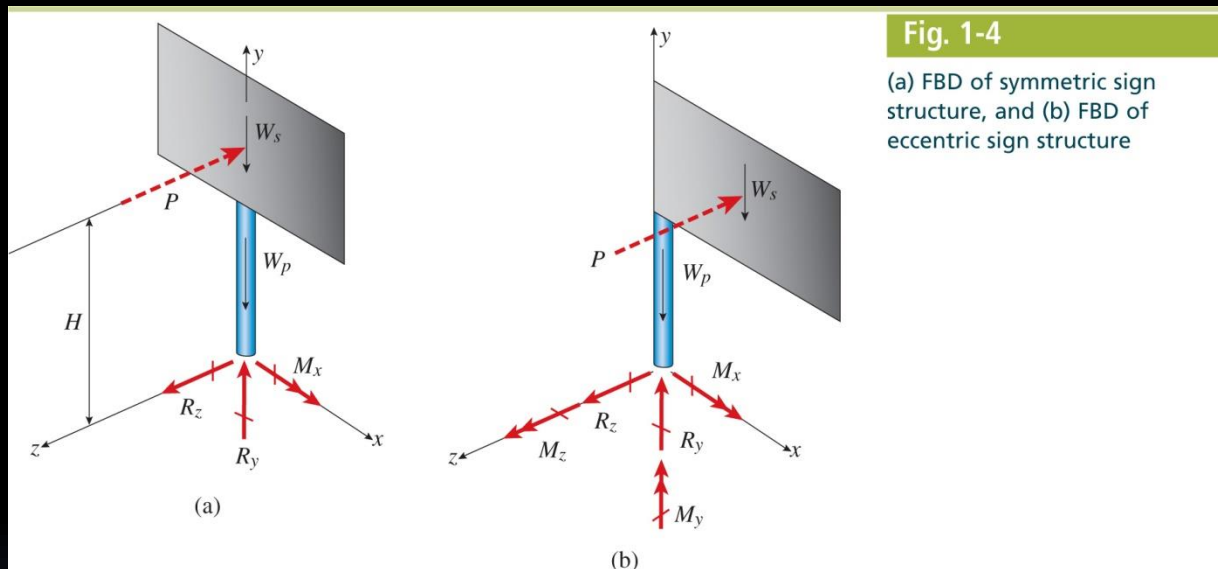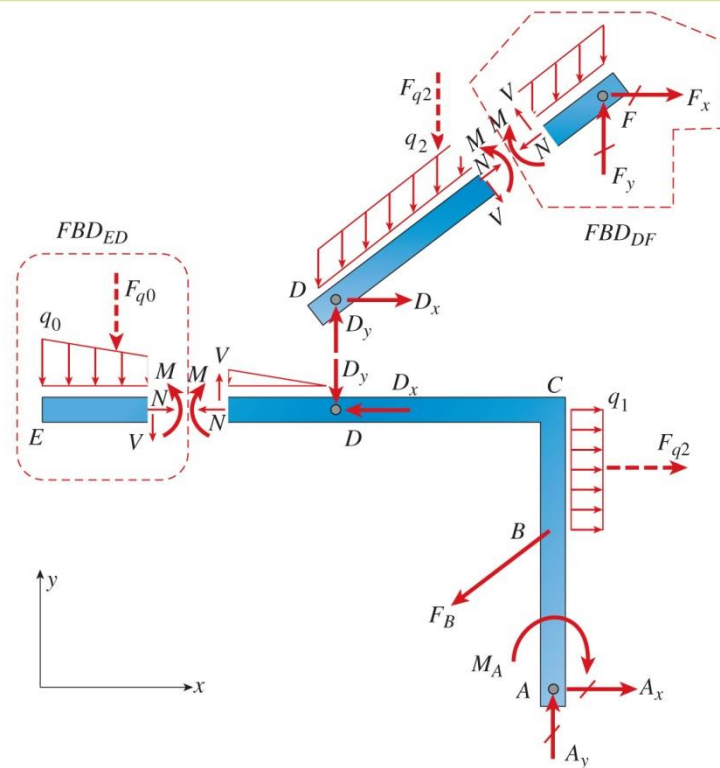
Fig. 1-4

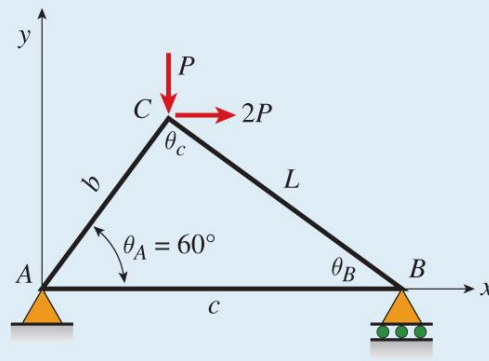(a) FBD of symmetric sign structure, and (b) FBD of eccentric sign structure
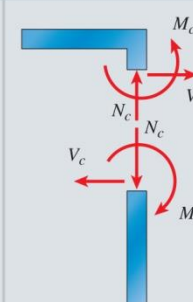
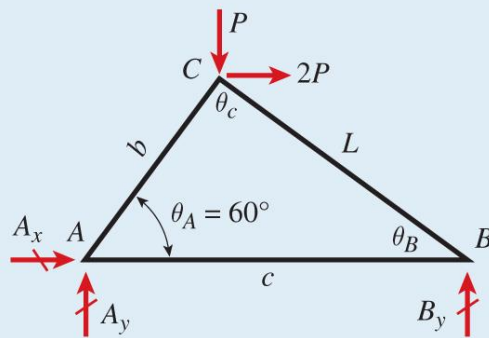**Fig. 1-5**

FBD's for internal stress resultants in *ED* and *DF*

Fig. 1-6
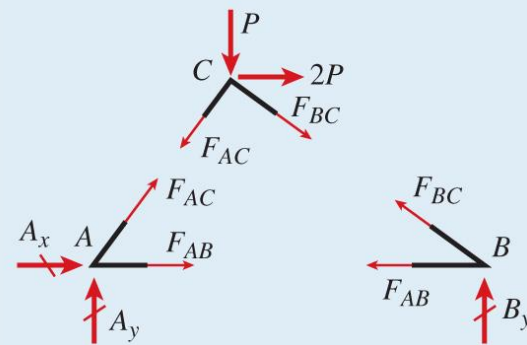
Example 1-1: Plane truss static analysis for joint loads
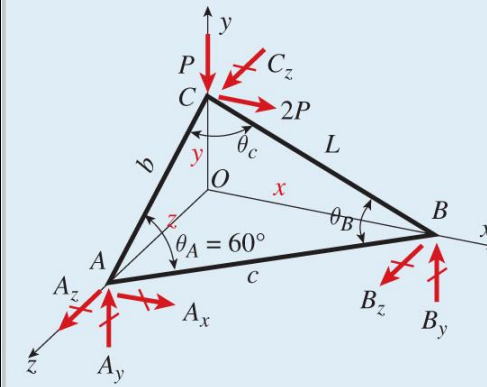
Fig. 1-7

Example 1-1: FBD of plane truss
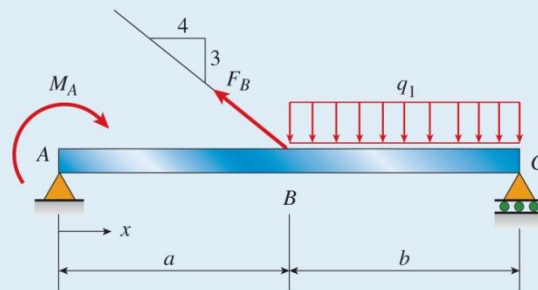
Fig. 1-8

Example 1-1: FBD of each joint of plane truss

Fig. 1-9

Example 1-1: FBD of space truss (extended version of plane truss)
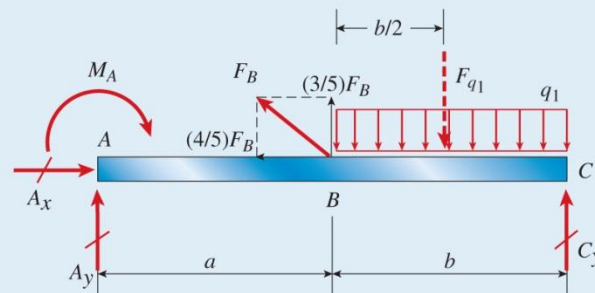
Fig. 1-10

Example 1-2: Beam static analysis for support reactions
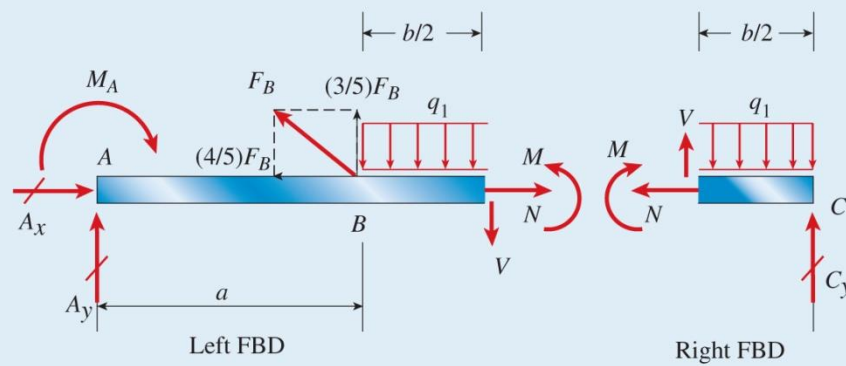
Fig. 1-11
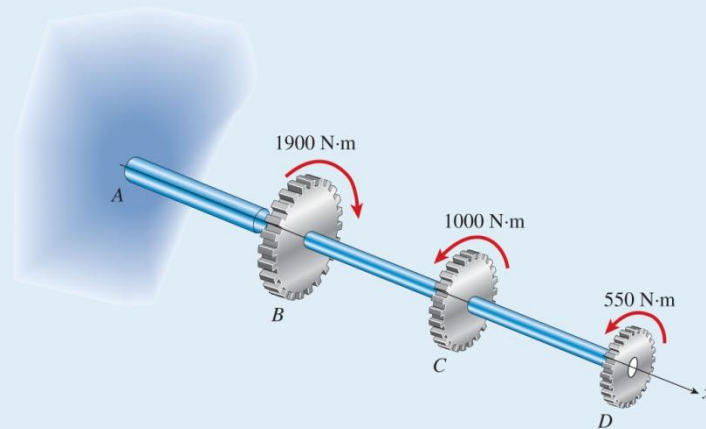
Example 1-2: FBD of beam

Fig. 1-12

Example 1-2: Left and right FBDs of beam

Left FBD

Right FBD
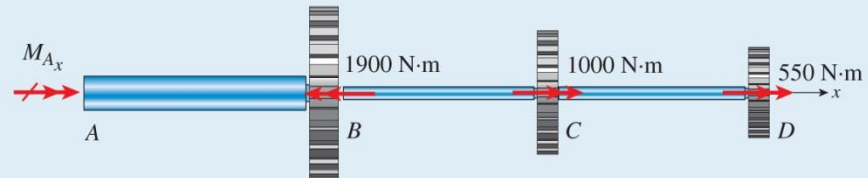
Fig. 1-13

Example 1-3: Stepped circular shaft in torsion

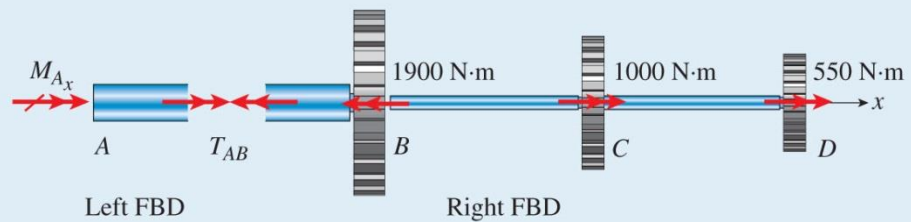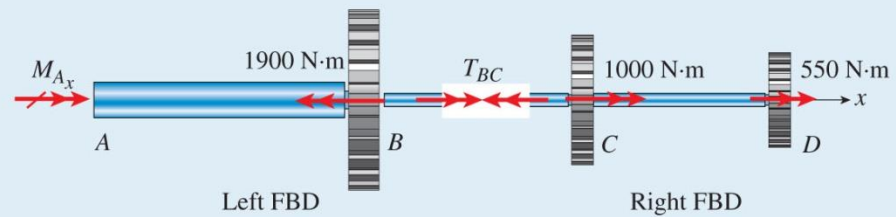Fig. 1-14

Example 1-3: FBD of overall shaft

Fig. 1-15a

Example 1-3: Left and right FBDs of shaft for each segment

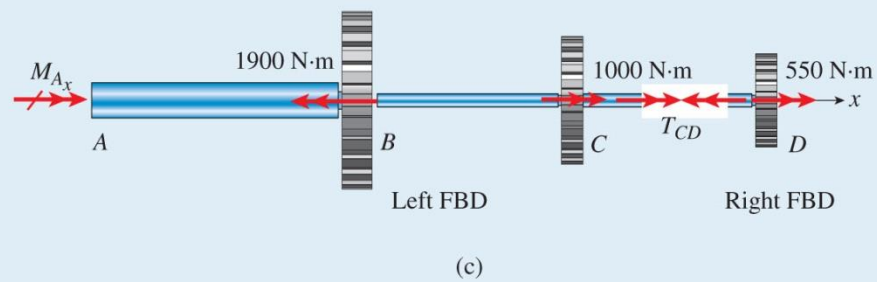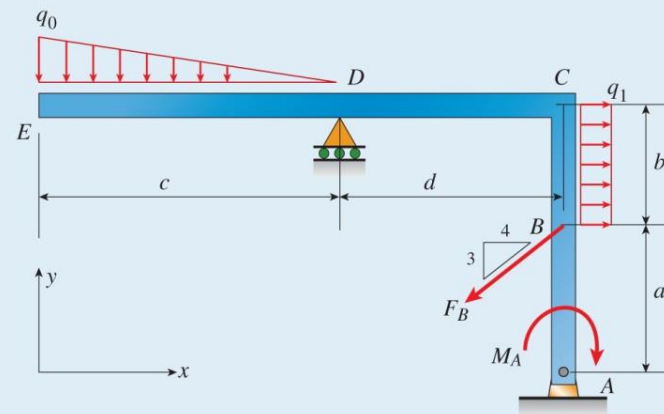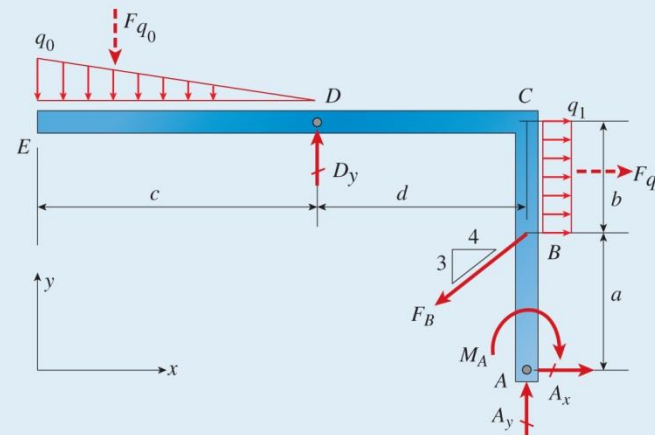Fig. 1-15b

(b)

Fig. 1-15c

(c)

Fig. 1-16

Example 1-4: Plane frame static analysis for support reactions

Fig. 1-17

Example 1-4: FBD of plane frame

Fig. 1-18

Example 1-4: Upper and lower FBDs of plane frame

Fig. 1-19

Structural members subjected to axial loads (the tow bar is in tension and the landing gear strut is in compression)

Landing gear strut

Tow bar
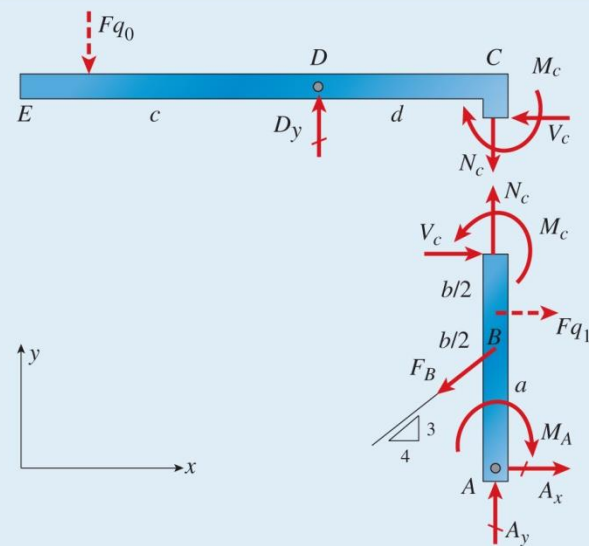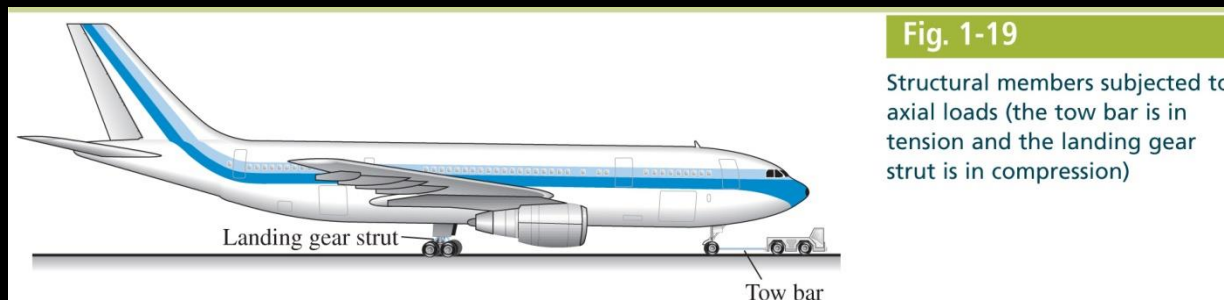
Fig. 1-20

Prismatic bar in tension: (a) free-body diagram of a segment of the bar, (b) segment of the bar before loading, (c) segment of the bar after loading, and (d) normal stresses in the bar

Fig. 1-21

Steel eyebar subjected to tensile loads P

Fig. 1-22

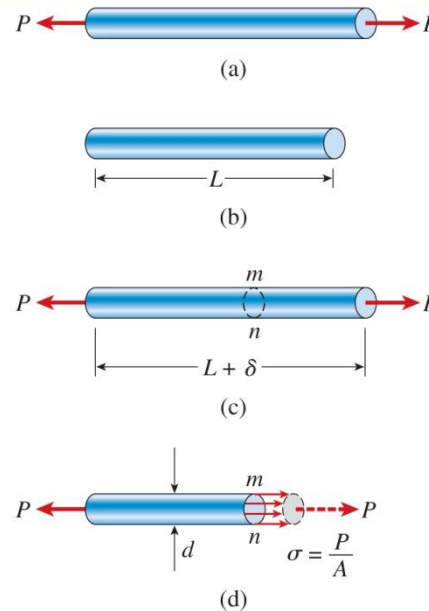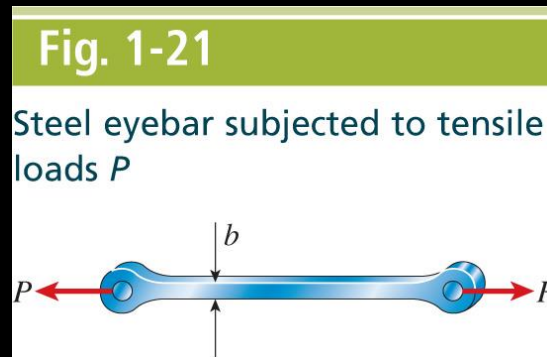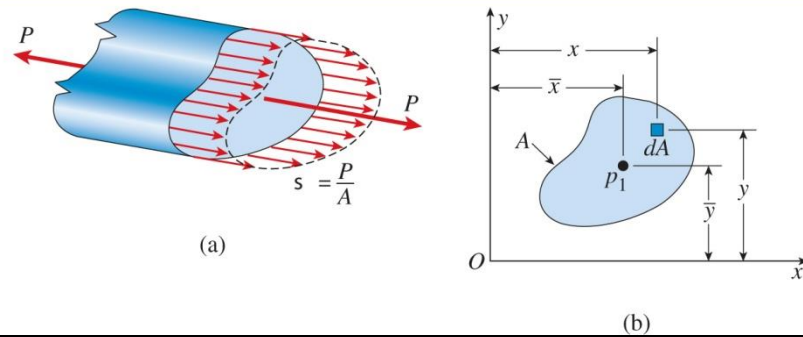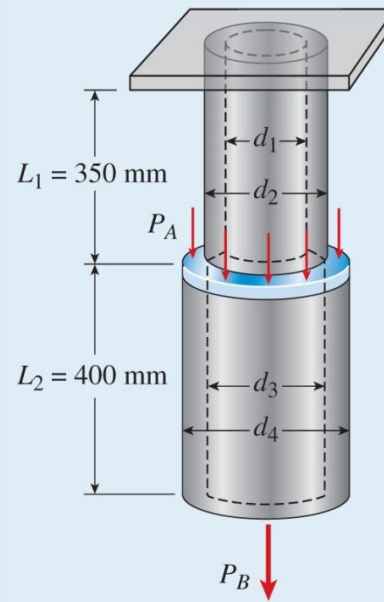Uniform stress distribution in a prismatic bar: (a) axial forces P, and (b) cross section of the bar

$$s = \frac{P}{A}$$

(a)

(b)

Fig. 1-23

Example 1-5: Two-tier hanging pipe stress analysis

$L_1 = 350$ mm

d_1

d_2

P_A

$L_2 = 400$ mm

d_3

d_4

P_B

Fig. 1-24a

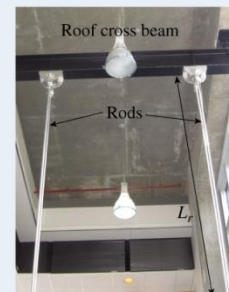Example 1-6: Hanger rods supporting steel staircase
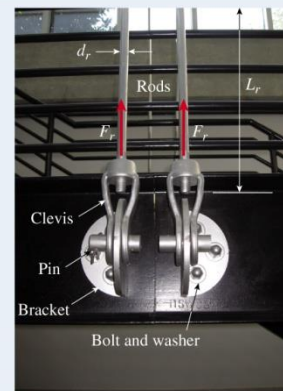
Components of hanger rod connection
(© Barry Goodno)

Fig. 1-24b

Side view of hanger rod and bracket
(© Barry Goodno)

Fig. 1-24c

Hanger rod attached to cross beam at roof
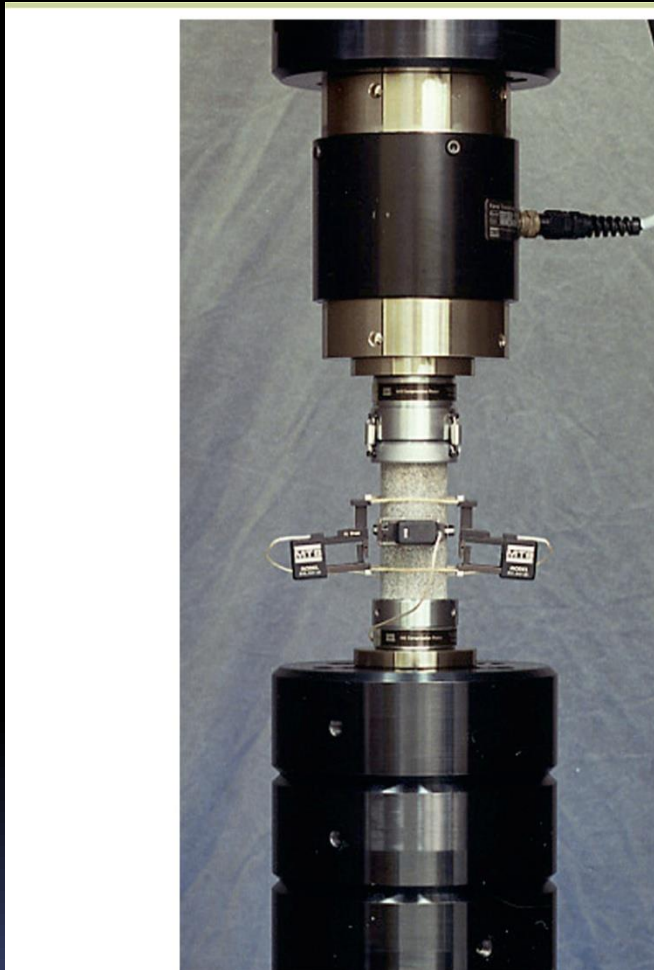(© Barry Goodno)

Fig. 1-25

Tensile-test machine with automatic data-processing system (Courtesy of MTS Systems Corporation)

Fig. 1-26

Typical tensile-test specimen with extensometer attached; the specimen has just fractured in tension. (Courtesy of MTS Systems Corporation)
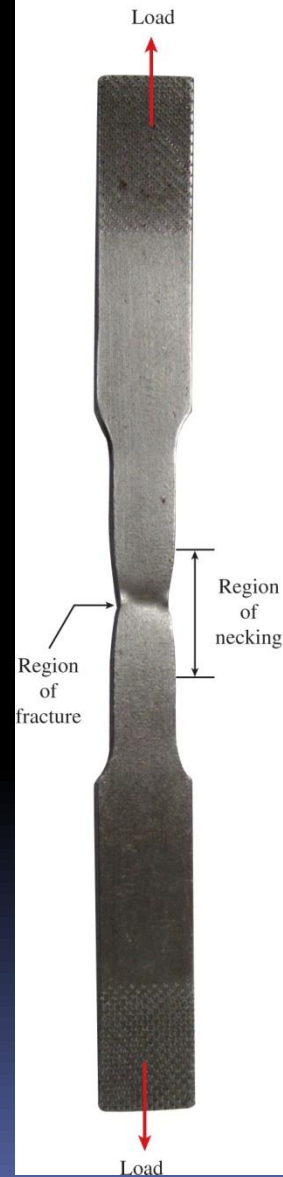
Fig. 1-27

Rock sample being tested in compression to obtain compressive strength, elastic modulus and Poisson's ratio (Courtesy of MTS Systems Corporation)
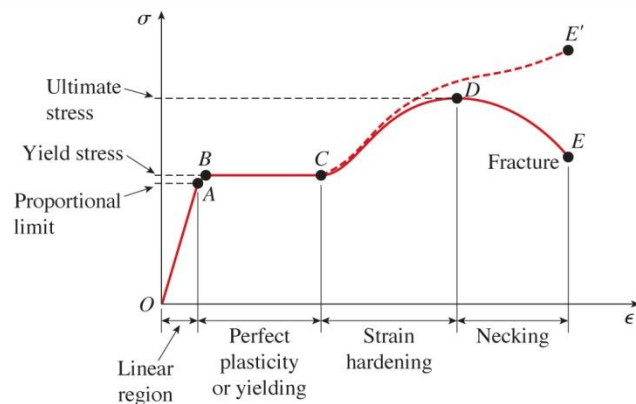
Fig. 1-28

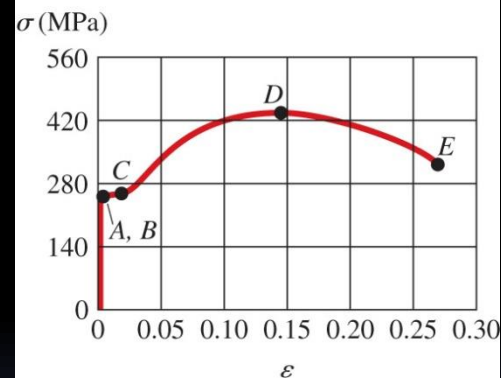Stress-strain diagram for a typical structural steel in tension (not to scale)

Fig. 1-29
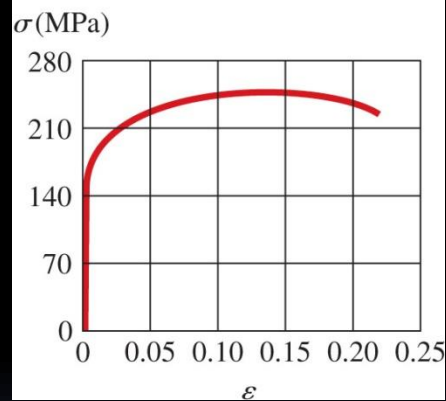
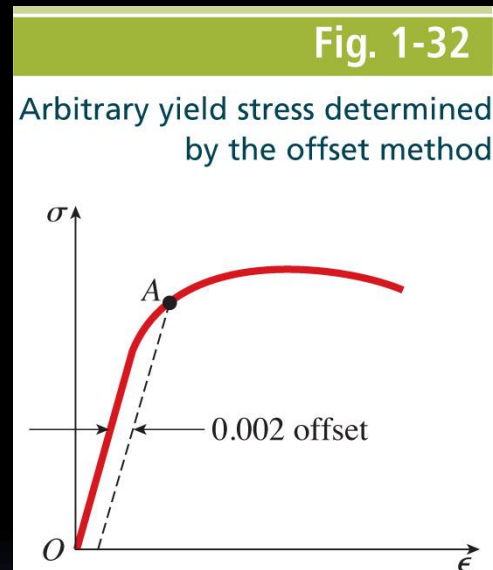Necking of a mild-steel bar in tension (© Barry Goodno)

Fig. 1-30

Stress-strain diagram for a typical structural steel in tension (drawn to scale)

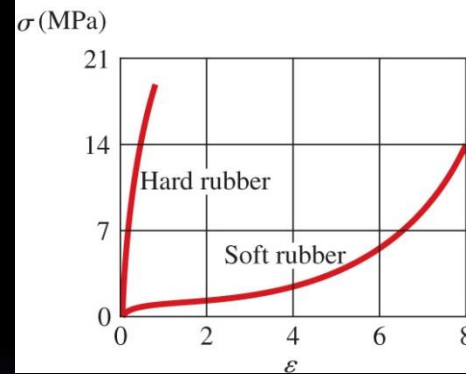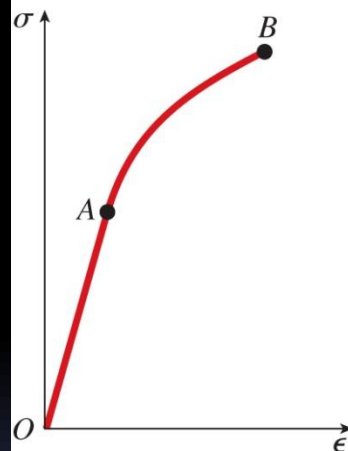Fig. 1-31

Typical stress-strain diagram for an aluminum alloy

Fig. 1-32

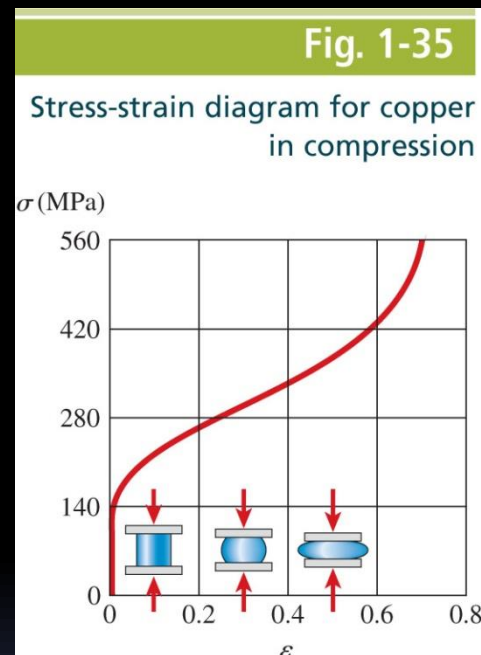Arbitrary yield stress determined by the offset method

Fig. 1-33

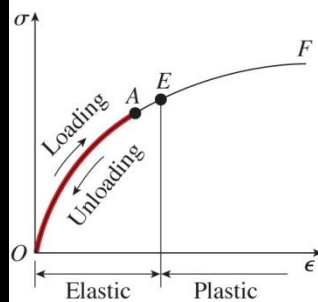Stress-strain curves for two kinds of rubber in tension

Fig. 1-34

Typical stress-strain diagram for a brittle material showing the proportional limit (point A) and fracture stress (point B)

Fig. 1-35
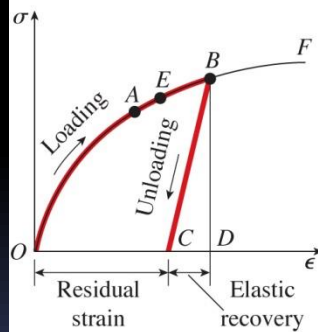
Stress-strain diagram for copper in compression

Fig. 1-36

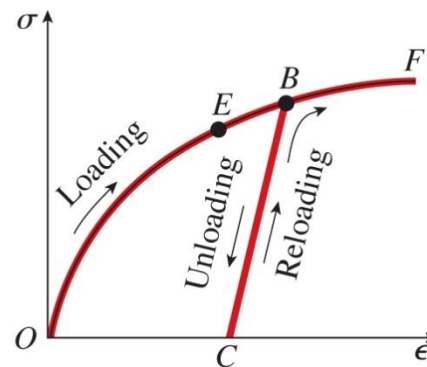Stress-strain diagrams illustrating (a) elastic behavior, and (b) partially elastic behavior
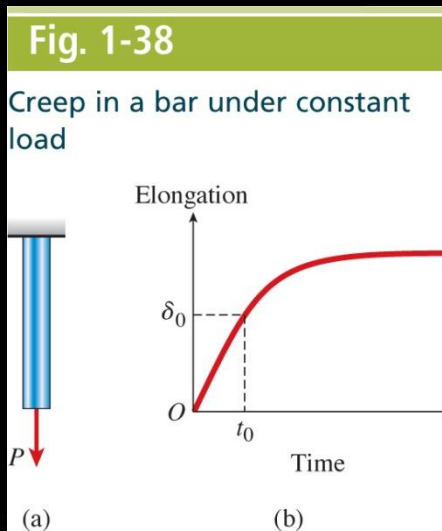
Fig. 1-37

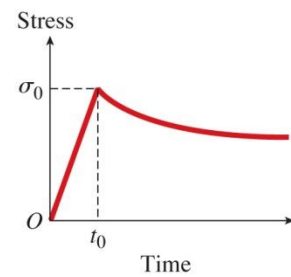Reloading of a material and raising of the elastic and proportional limits

Fig. 1-38

Creep in a bar under constant load
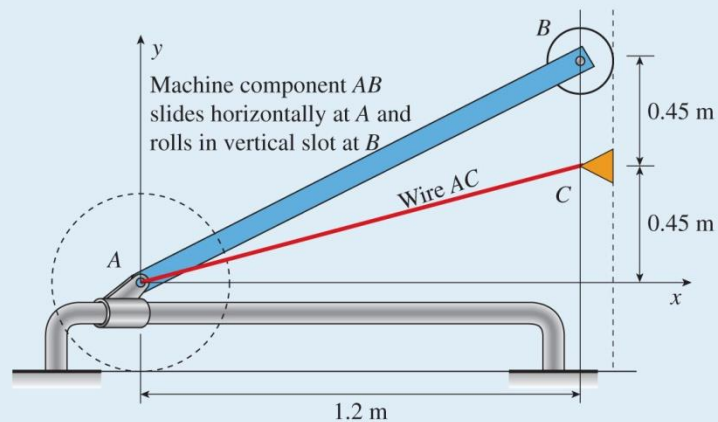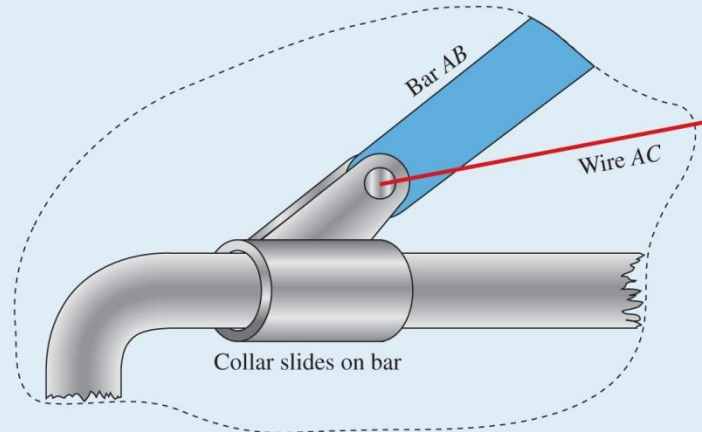
Fig. 1-39

Relaxation of stress in a wire under constant strain

Fig. 1-40

Example 1-7: Rigid bar supported by copper alloy wire

Bar AB

Wire AC

Collar slides on bar

y

Machine component AB slides horizontally at A and rolls in vertical slot at B
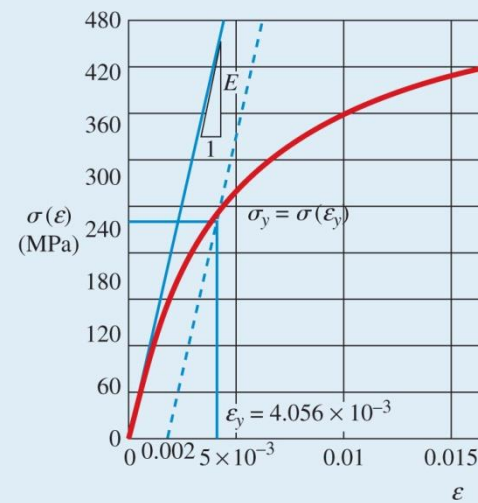
Wire AC

B

0.45 m

C

0.45 m

A

x

1.2 m

Fig. 1-41
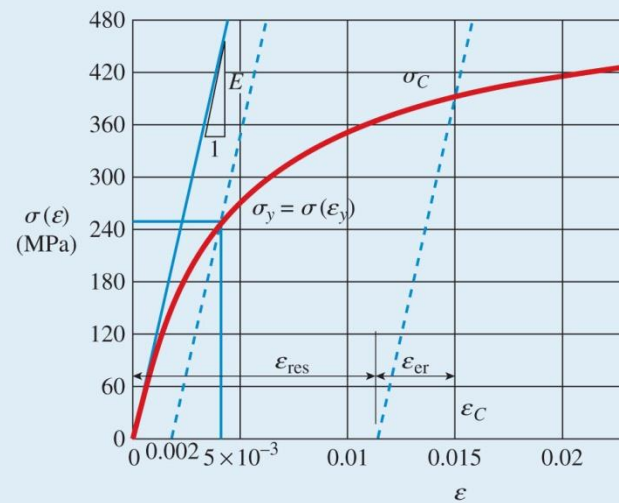
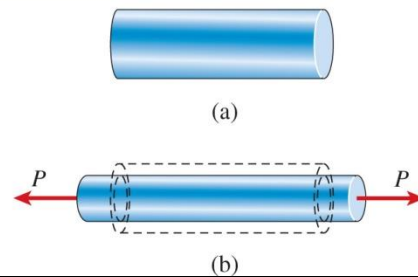Stress-strain curve for copper alloy wire in Example 1-7
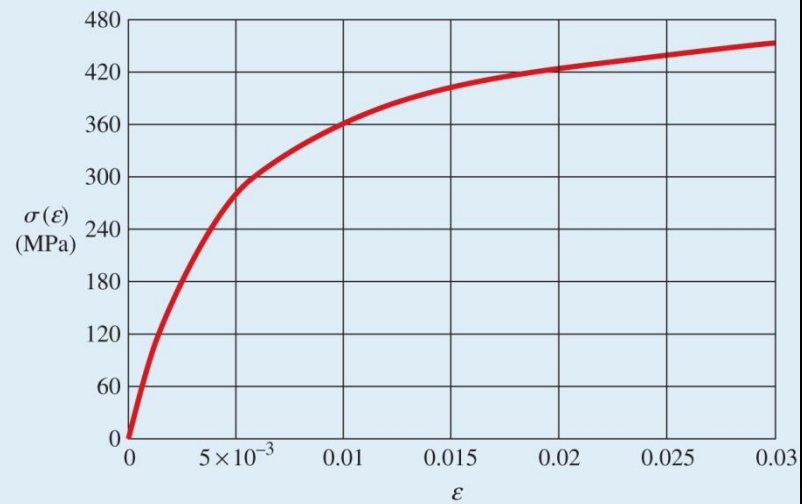
Fig. 1-42

Modulus of elasticity E, 0.2% offset line and yield stress σ_y and strain ε_y for copper alloy wire in Example 1-7
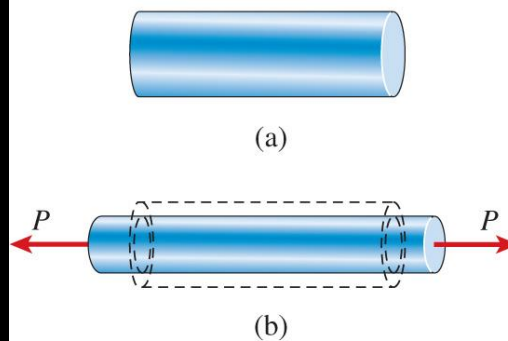
Fig. 1-43

Residual strain (ε_{res}) and elastic recovery strain (ε_{er}) for copper alloy wire in Example 1-7
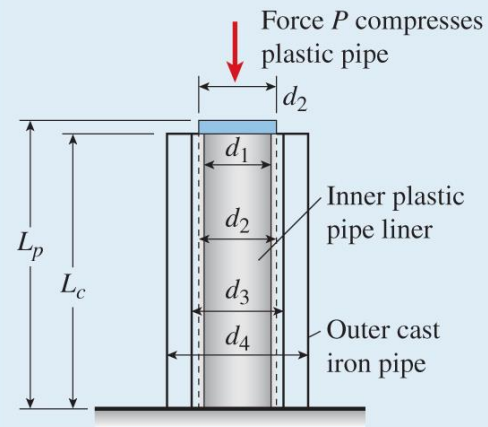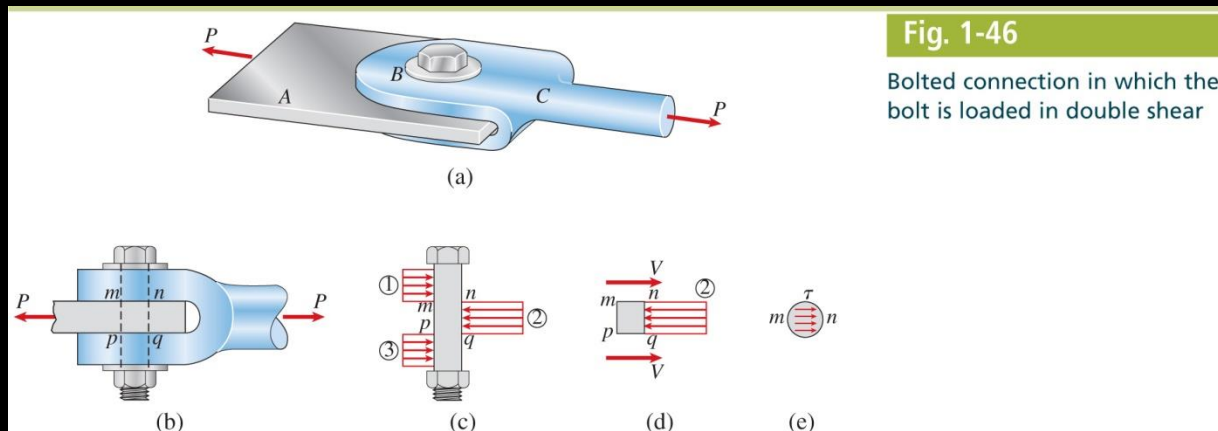
Fig. 1-44

Axial elongation and lateral contraction of a prismatic bar in tension: (a) bar before loading, and (b) bar after loading. (The deformations of the bar are highly exaggerated.)

Fig. 1-44 (Repeated)

(a)

(b)

Fig. 1-45

Example 1-8: Plastic pipe compressed inside cast iron pipe

Fig. 1-46

Bolted connection in which the bolt is loaded in double shear

Fig. 1-47

Bolted connection in which the bolt is loaded in single shear

Fig. 1-48

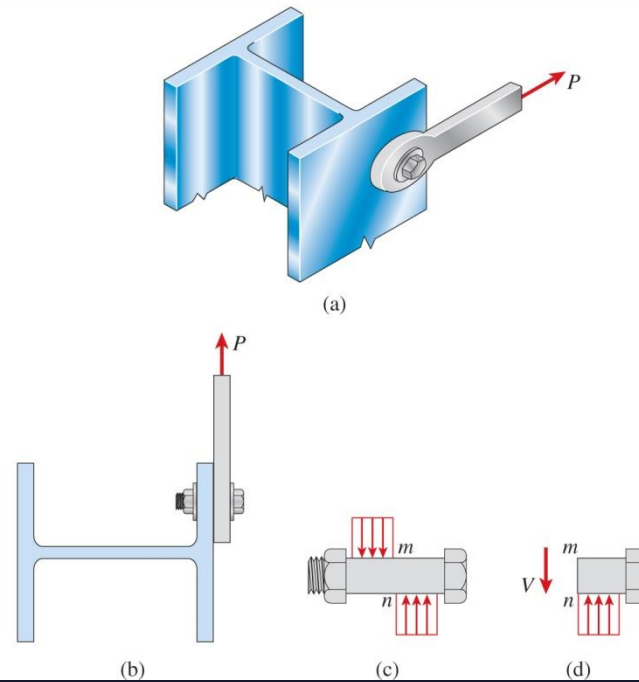Failure of a bolt in single shear
(© Barry Goodno)

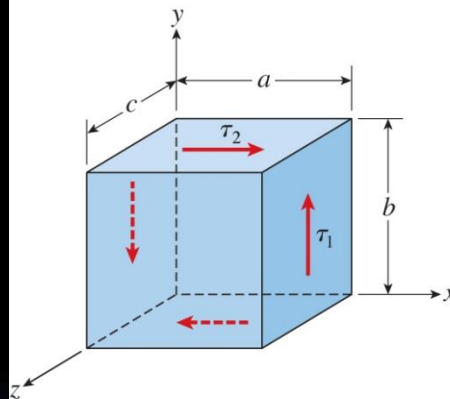Fig. 1-49

Small element of material subjected to shear stresses
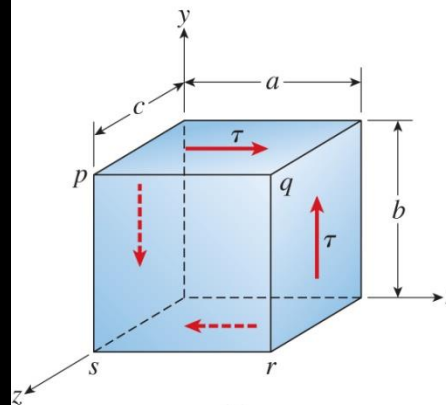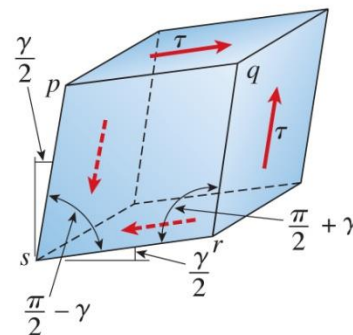
Fig. 1-50

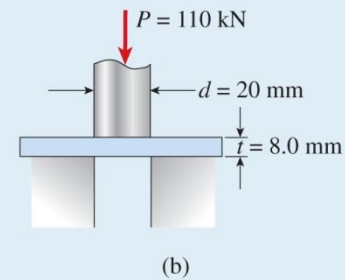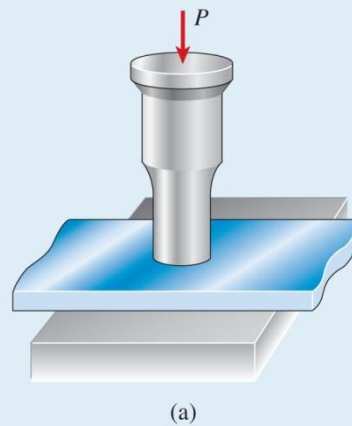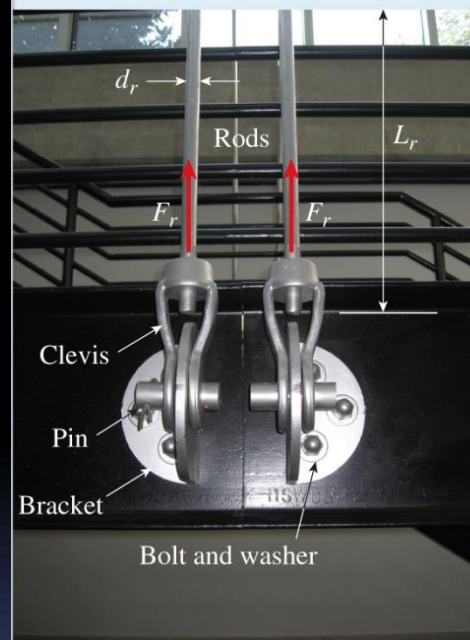Element of material subjected to shear stresses and strains

Fig. 1-51

Example 1-9: Punching a hole in a steel plate

(a)

$P = 110$ kN
$d = 20$ mm
$t = 8.0$ mm

(b)

Fig. 1-52a

Example 1-10: Semi-circular plate connection for steel staircase

Fig. 1-52b

Side view

Fig. 1-52c
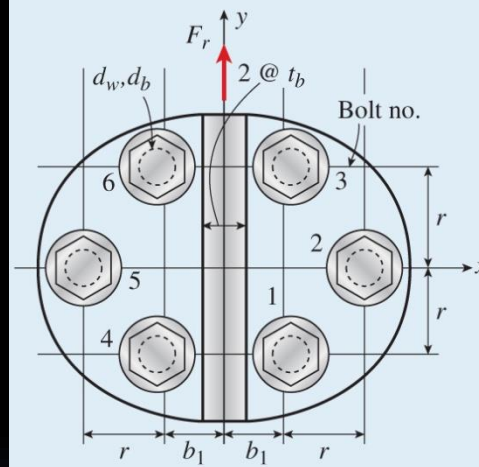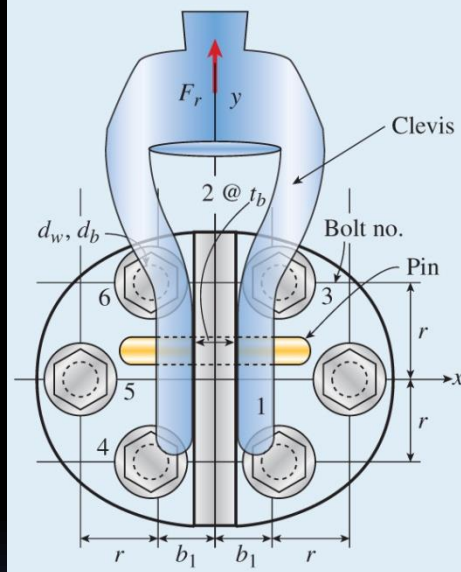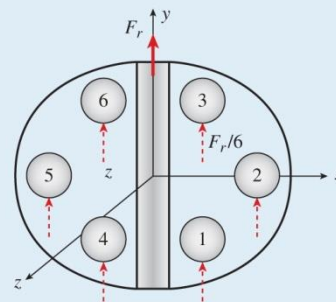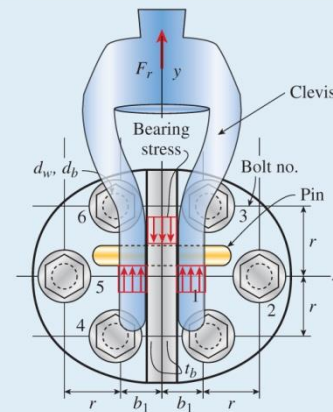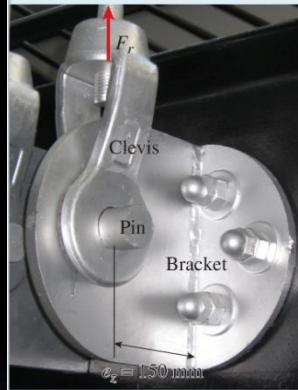
Fig. 1-52d

Fig. 1-52e

In-plane shear force in each bolt

Fig. 1-52f

Bearing stresses on pin and bracket
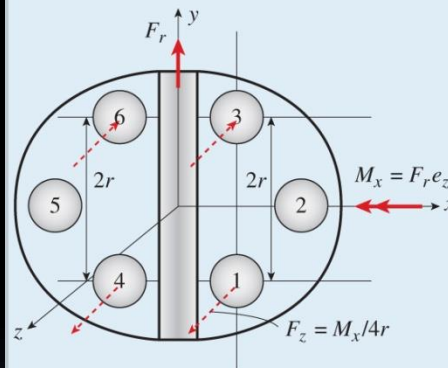
Fig. 1-52g

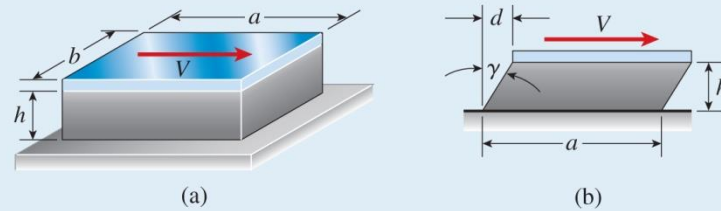Rod force is applied at distance e_z from back plate of bracket. (© Barry Goodno)

Fig. 1-52h

Moment M_x can be converted into two force couples, each equal to $F_z \times 2r$, which act on bolt pairs 1-3 and 4-6.
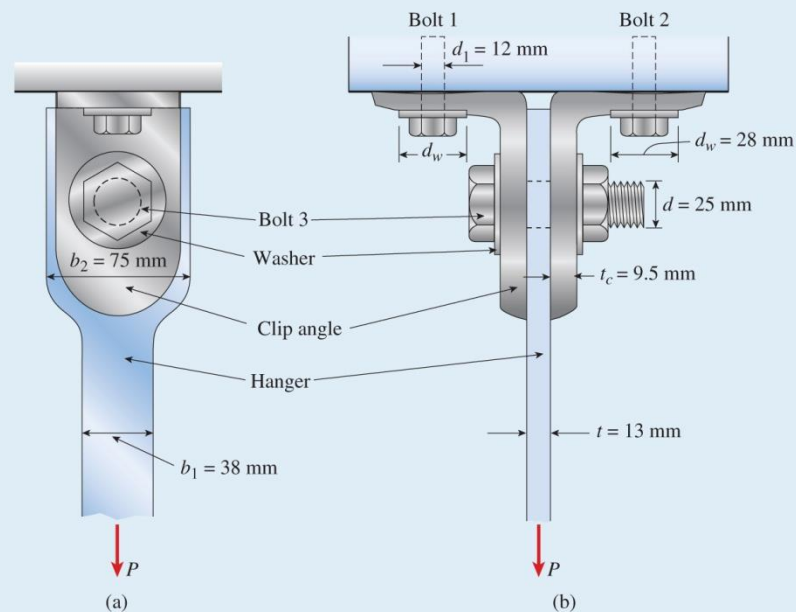
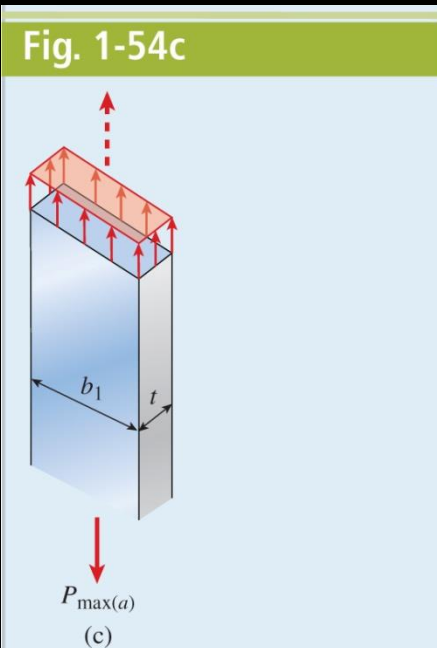$M_x = F_r e_z$

$F_z = M_x/4r$

Fig. 1-53

Example 1-11. Bearing pad in shear

(a)

(b)

Fig. 1-54

Example 1-12: Vertical hanger subjected to a tensile load P: (a) front view of bolted connection, and (b) side view of connection
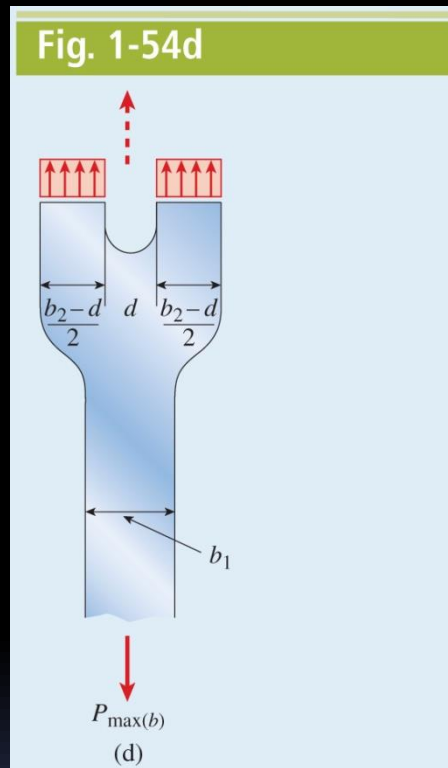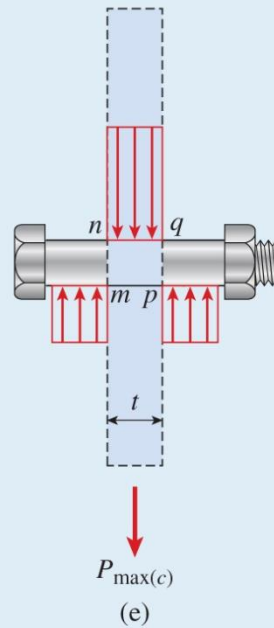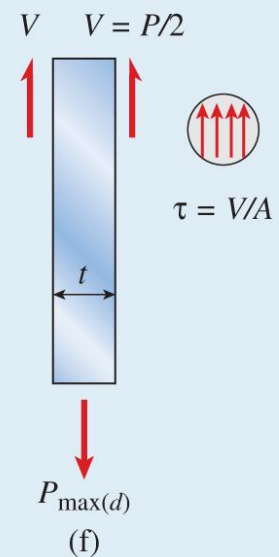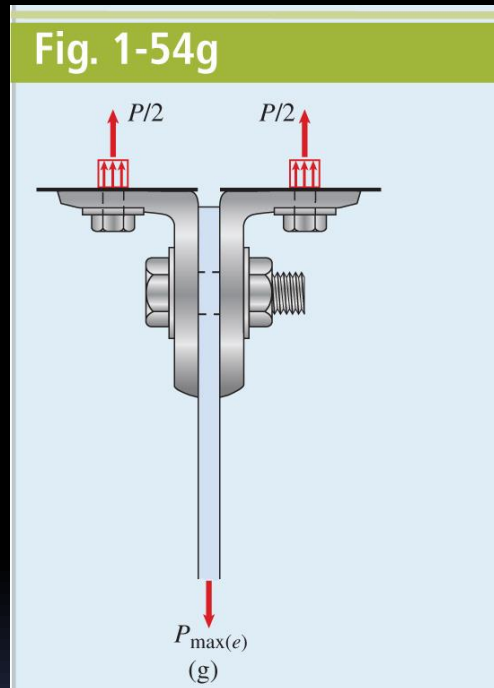
Fig. 1-54c

$P_{max(a)}$

(c)

Fig. 1-54d

(d)

Fig. 1-54e

Fig. 1-54f

$V \qquad V = P/2$

$\tau = V/A$

t

$P_{\max(d)}$

(f)

Fig. 1-54g

$P/2$ $P/2$

$P_{\max(e)}$

(g)

Fig. 1-54h

$P_{max(f)}/2$
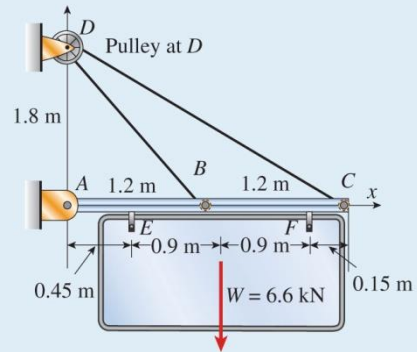
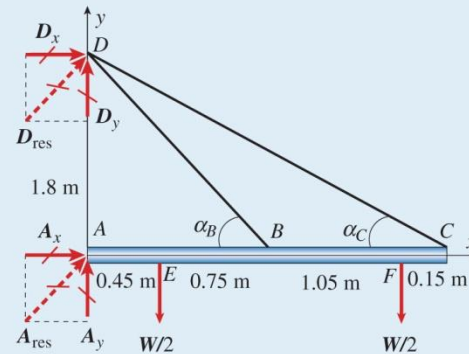(h)

Fig. 1-54i

$P_{\max(g)}/2$
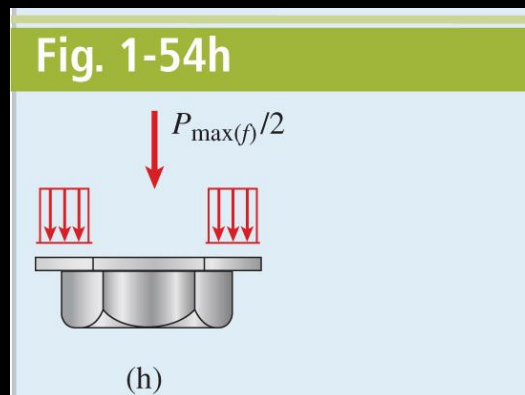
(i)
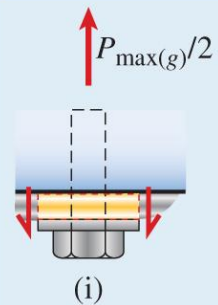
Fig. 1-55

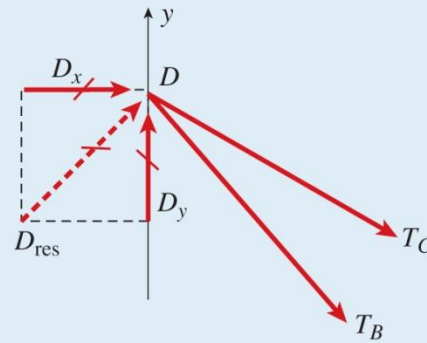Example 1-13: Cable-supported pipe *ABC* carrying sign of weight *W*

Fig. 1-56

Example 1-13: Free-body diagram of entire structure

Fig. 1-57

Free-body diagram of joint D

Fig. 1-58

Free-body diagram of member ABC