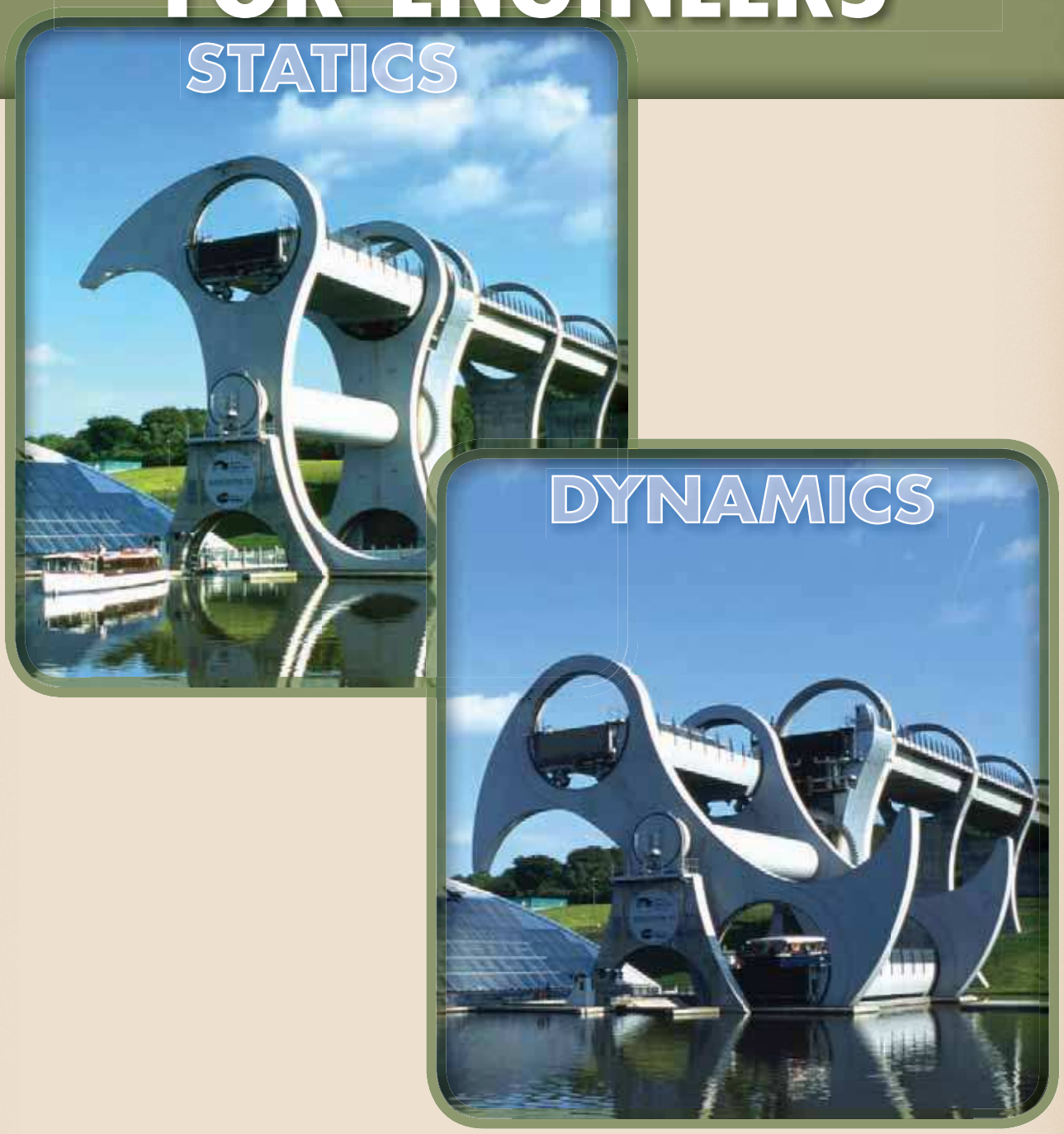
VECTOR MECHANICS FOR ENGINEERS



BEER | JOHNSTON | MAZUREK | CORNWELL | EISENBERG

Ninth Edition

NINTH EDITION

VECTOR MECHANICS FOR ENGINEERS

Statics and Dynamics

Ferdinand P. Beer
Late of Lehigh University

E. Russell Johnston, Jr.
University of Connecticut

David F. Mazurek
U.S. Coast Guard Academy

Phillip J. Cornwell
Rose-Hulman Institute of Technology

Elliot R. Eisenberg
The Pennsylvania State University

Mc Graw Hill **Higher Education**

Boston Burr Ridge, IL Dubuque, IA New York San Francisco St. Louis
Bangkok Bogotá Caracas Kuala Lumpur Lisbon London Madrid Mexico City
Milan Montreal New Delhi Santiago Seoul Singapore Sydney Taipei Toronto

The McGraw-Hill Companies

Mc Graw Hill Higher Education

VECTOR MECHANICS FOR ENGINEERS: STATICS & DYNAMICS, NINTH EDITION

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 0 QPV/QPV 0 9

ISBN 978–0–07–352940–0
MHID 0–07–352940–0

Global Publisher: *Raghothaman Srinivasan*
Senior Sponsoring Editor: *Bill Stenquist*
Director of Development: *Kristine Tibbetts*
Developmental Editor: *Lora Neyens*
Senior Marketing Manager: *Curt Reynolds*
Senior Project Manager: *Sheila M. Frank*
Senior Production Supervisor: *Sherry L. Kane*
Senior Media Project Manager: *Tammy Juran*
Designer: *Laurie B. Janssen*
Cover/Interior Designer: *Ron Bissell*
(USE) Cover Image: ©*John Peter Photography/Alamy*
Lead Photo Research Coordinator: *Carrie K. Burger*
Photo Research: *Sabina Dowell*
Supplement Producer: *Mary Jane Lampe*
Compositor: *Aptara®, Inc.*
Typeface: *10.5/12 New Caledonia*
Printer: *Quebecor World Versailles, KY*

The credits section for this book begins on page 1291 and is considered an extension of the copyright page.

Library of Congress Cataloging-in-Publication Data

Vector mechanics for engineers. Statics and dynamics / Ferdinand Beer . . . [et al.]. — 9th ed.
p. cm.
Includes index.
ISBN 978–0–07–352940–0 (combined vol. : hc : alk. paper) — ISBN 978–0–07–352923–3
(v. 1 — "Statics" : hc : alk. paper) — ISBN 978–0–07–724916–8 (v. 2 — "Dynamics" : hc : alk. paper)
1. Mechanics, Applied. 2. Vector analysis. 3. Statics. 4. Dynamics. I. Beer, Ferdinand Pierre, 1915–

TA350.B3552 2009
620.1′05—dc22

2008047184

www.mhhe.com

Contents

13 Kinetics of Particles: Energy and Momentum Methods 754

14 Systems of Particles 854

15 Kinematics of Rigid Bodies 914

16 Plane Motion of Rigid Bodies: Forces and Accelerations 1024

17 Plane Motion of Rigid Bodies: Energy and Momentum Methods 1080

18 Kinetics of Rigid Bodies in Three Dimensions 1144

List of Symbols

a	Constant; radius; distance
$\mathbf{A}$, $\mathbf{B}$, $\mathbf{C}$, . . .	Reactions at supports and connections
A, B, C, . . .	Points
A	Area
b	Width; distance
c	Constant
C	Centroid
d	Distance
e	Base of natural logarithms
$\mathbf{F}$	Force; friction force
g	Acceleration of gravity
G	Center of gravity; constant of gravitation
h	Height; sag of cable
$\mathbf{i}$, $\mathbf{j}$, $\mathbf{k}$	Unit vectors along coordinate axes
I, I_x, . . .	Moments of inertia
$\bar{I}$	Centroidal moment of inertia
I_{xy}, . . .	Products of inertia
J	Polar moment of inertia
k	Spring constant
k_x, k_y, k_O	Radii of gyration
$\bar{k}$	Centroidal radius of gyration
l	Length
L	Length; span
m	Mass
$\mathbf{M}$	Couple; moment
$\mathbf{M}_O$	Moment about point O
$\mathbf{M}_O^R$	Moment resultant about point O
M	Magnitude of couple or moment; mass of earth
M_{OL}	Moment about axis OL
$\mathbf{N}$	Normal component of reaction
O	Origin of coordinates
p	Pressure
$\mathbf{P}$	Force; vector
$\mathbf{Q}$	Force; vector
$\mathbf{r}$	Position vector
r	Radius; distance; polar coordinate
$\mathbf{R}$	Resultant force; resultant vector; reaction
R	Radius of earth
$\mathbf{s}$	Position vector
s	Length of arc; length of cable
$\mathbf{S}$	Force; vector
t	Thickness
$\mathbf{T}$	Force
T	Tension
U	Work

$\mathbf{V}$	Vector product; shearing force
V	Volume; potential energy; shear
w	Load per unit length
$\mathbf{W}$, W	Weight; load
x, y, z	Rectangular coordinates; distances
$\bar{x}, \bar{y}, \bar{z}$	Rectangular coordinates of centroid or center of gravity
α, β, γ	Angles
γ	Specific weight
δ	Elongation
$\delta\mathbf{r}$	Virtual displacement
δU	Virtual work
$\boldsymbol{\lambda}$	Unit vector along a line
η	Efficiency
θ	Angular coordinate; angle; polar coordinate
μ	Coefficient of friction
ρ	Density
ϕ	Angle of friction; angle

Appendix

Fundamentals of Engineering Examination

Engineers are required to be licensed when their work directly affects the public health, safety, and welfare. The intent is to ensure that engineers have met minimum qualifications involving competence, ability, experience, and character. The licensing process involves an initial exam, called the *Fundamentals of Engineering Examination*, professional experience, and a second exam, called the *Principles and Practice of Engineering*. Those who successfully complete these requirements are licensed as a *Professional Engineer*. The exams are developed under the auspices of the *National Council of Examiners for Engineering and Surveying*.

The first exam, the *Fundamentals of Engineering Examination*, can be taken just before or after graduation from a four-year accredited engineering program. The exam stresses subject material in a typical undergraduate engineering program, including statics and dynamics. The topics included in the exam cover much of the material in this book. The following is a list of the main topic areas, with references to the appropriate sections in this book. Also included are problems that can be solved to review this material.

Concurrent Force Systems (2.2–2.9; 2.12–2.14)
Problems: 2.33, 2.35, 2.36, 2.37, 2.73, 2.83, 2.92, 2.93, 2.97

Vector Forces (3.4–3.11)
Problems: 3.16, 3.18, 3.25, 3.31, 3.38, 3.40

Equilibrium in Two Dimensions (2.11; 4.1–4.7)
Problems: 4.5, 4.13, 4.14, 4.17, 4.29, 4.38, 4.66, 4.75

Equilibrium in Three Dimensions (2.15; 4.8–4.9)
Problems: 4.101, 4.104, 4.103, 4.106, 4.115, 4.117, 4.127, 4.132, 4.140

Centroid of an Area (5.2–5.7)
Problems: 5.6, 5.18, 5.29, 5.35, 5.40, 5.56, 5.58, 5.99, 5.103, 5.104, 5.125

Analysis of Trusses (6.2–6.7)
Problems: 6.3, 6.4, 6.33, 6.43, 6.44, 6.56

Equilibrium of Two-Dimensional Frames (6.9–6.11)
Problems: 6.76, 6.80, 6.87, 6.91, 6.92

Shear and Bending Moment (7.3–7.6)
Problems: 7.22, 7.25, 7.31, 7.36, 7.45, 7.49, 7.70, 7.83

Friction (8.2–8.5; 8.10)
Problems: 8.11, 8.15, 8.21, 8.30, 8.50, 8.53, 8.101, 8.104, 8.105

Moments of Inertia (9.2–9.10)
Problems: 9.5, 9.31, 9.32, 9.33, 9.77, 9.78, 9.84, 9.89, 9.101, 9.103

Kinematics (11.1–11.6; 11.9–11.14, 15.2–15.8)
Problems: 11.4, 11.5, 11.34, 11.61, 11.69, 11.97, 15.6, 15.30, 15.40, 15.57, 15.65, 15.83, 15.118, 15.141

Force, Mass, and Acceleration (12.1–12.6, 16.2–16.8)
Problems: 12.5, 12.6, 12.28, 12.30, 12.37, 12.46, 12.51, 12.56, 16.3, 16.5, 16.11, 16.25, 16.30, 16.50, 16.58, 16.63, 16.76, 16.85, 16.138

Work and Energy (13.1–13.6; 13.8; 17.1–17.7)
Problems: 13.5, 13.7, 13.15, 13.22, 13.39, 13.41, 13.50, 13.62, 13.64, 13.68, 17.1, 17.2, 17.18, 17.28

Impulse and Momentum (13.10–13.15; 17.8–17.12)
Problems: 13.121, 13.126, 13.129, 13.134, 13.146, 13.157, 13.159, 13.170, 17.53, 17.59, 17.69, 17.74, 17.96, 17.102, 17.106

Vibration (19.1–19.3; 19.5–19.7)
Problems: 19.1, 19.3, 19.11, 19.17, 19.23, 19.27, 19.50, 19.55, 19.66, 19.76, 19.83, 19.85, 19.101, 19.105, 19.115

Friction (Problems involving friction occur in each of the above subjects)

Index

A

B

C

D

E

F

G

H

M

N

O

P

Q

R

S

T

U

Answers to Problems

Answers to problems with a number set in straight type are given on this and the following pages. Answers to problems set in italic are not listed.

CHAPTER 2

2.1 179 N ◹ 75.1°.
2.2 77.1 lb ◸ 85.4°.
2.3 139.1 lb ◸ 67.0°.
2.5 (*a*) 76.1°. (*b*) 336 lb.
2.7 (*a*) 37.1°. (*b*) 73.2 N.
2.8 (*a*) 44.7 N. (*b*) 107.1 N.
2.9 (*a*) 3660 N. (*b*) 3730 N.
2.10 2600 N ◹ 53.5°.
2.11 (*a*) 392 lb. (*b*) 346 lb.
2.13 (*a*) 21.1 N ↓. (*b*) 45.3 N.
2.14 (*a*) 368 lb →. (*b*) 213 lb.
2.15 77.1 lb ◸ 85.4°.
2.16 139.1 lb ◸ 67.0°.
2.17 3.30 kN ◹ 66.6°.
2.19 21.8 kN ◹ 86.6°.
2.21 (800 N) 640 N, 480 N; (424 N) −224 N, −360 N; (408 N) 192.0 N, −360 N.
2.22 (29 lb) 21.0 lb, 20.0 lb; (50 lb) −14.00 lb, 48.0 lb; (51 lb) 24.0 lb, −45.0 lb.
2.23 (40 lb) 20.0 lb, −34.6 lb; (50 lb) −38.3 lb, −32.1 lb; (60 lb) 54.4 lb, 25.4 lb.
2.25 (*a*) 523 lb. (*b*) 428 lb.
2.26 (*a*) 2190 N. (*b*) 2060 N.
2.27 (*a*) 194.9 N. (*b*) 153.6 N.
2.30 (*a*) 610 lb. (*b*) 500 lb.
2.31 38.6 lb ◿ 36.6°.
2.32 251 N ◺ 85.3°.
2.34 654 N ◹ 21.5°.
2.35 309 N ◸ 86.6°.
2.36 226 N ◸ 62.3°.
2.37 203 lb ◿ 8.46°.
2.39 (*a*) 21.7°. (*b*) 229 N.
2.40 (*a*) 580 N. (*b*) 300 N.
2.42 (*a*) 56.3°. (*b*) 204 lb.
2.43 (*a*) 2.13 kN. (*b*) 1.735 kN.
2.45 (*a*) 305 N. (*b*) 514 N.
2.47 (*a*) 1244 lb. (*b*) 115.4 lb.
2.48 (*a*) 172.7 lb. (*b*) 231 lb.
2.49 $F_A = 1303$ lb; $F_B = 420$ lb.
2.51 $F_C = 6.40$ kN; $F_D = 4.80$ kN.
2.52 $F_B = 15.00$ kN; $F_C = 8.00$ kN.
2.53 (*a*) 52.0 lb. (*b*) 45.0 lb.
2.55 (*a*) 1213 N. (*b*) 166.3 N.
2.56 (*a*) 863 N. (*b*) 1216 N.
2.57 (*a*) 784 N. (*b*) 71.0°.
2.59 (*a*) 60.0°. (*b*) 230 lb.
2.60 5.80 m.
2.61 (*a*) 1081 N. (*b*) 82.5°.
2.62 (*a*) 1294 N. (*b*) 62.5°.
2.63 (*a*) 10.98 lb. (*b*) 30.0 lb.
2.65 (*a*) 602 N ◺ 46.8°. (*b*) 1365 N ◸ 46.8°.
2.67 (*a*) 300 lb. (*b*) 300 lb. (*c*) 200 lb. (*d*) 200 lb. (*e*) 150.0 lb.
2.68 (*b*) 200 lb. (*d*) 150.0 lb.
2.69 (*a*) 1293 N. (*b*) 2220 N.
2.71 (*a*) +390 N, +614 N, +181.8 N. (*b*) 58.7°, 35.0°, 76.0°.
2.72 (*a*) −130.1 N, +816 N, +357 N. (*b*) 98.3°, 25.0°, 66.6°.
2.73 (*a*) 288 N. (*b*) 67.5°, 30.0°, 108.7°.
2.74 (*a*) 100.0 N. (*b*) 112.5°, 30.0°, 108.7°.
2.76 (*a*) 80.0 lb. (*b*) 104.5°, 30.0°, 64.3°.
2.77 (*a*) +56.4 lb, −103.9 lb, −20.5 lb. (*b*) 62.0°, 150.0°, 99.8°.
2.79 $F = 570$ N; $\theta_x = 55.8°$, $\theta_y = 45.4°$, $\theta_z = 116.0°$.
2.81 (*a*) 118.2°. (*b*) $F_x = 36.0$ lb, $F_y = -90.0$ lb; $F = 110.0$ lb.
2.82 (*a*) 114.4°. (*b*) $F_y = 694$ lb, $F_z = 855$ lb; $F = 1209$ lb.
2.84 (*a*) $F_x = 194.0$ N, $F_z = 108.0$ N. (*b*) $\theta_y = 105.1°$, $\theta_z = 62.0°$.
2.85 +100.0 lb, +500 lb, −125.0 lb.
2.86 +50.0 lb, +250 lb, +185.0 lb.
2.87 +240 N, −255 N, +160.0 N.
2.89 −1125 N, +750 N, +450 N.
2.91 515 N; $\theta_x = 70.2°$, $\theta_y = 27.6°$, $\theta_z = 71.5°$.
2.92 515 N; $\theta_x = 79.8°$, $\theta_y = 33.4°$, $\theta_z = 58.6°$.
2.94 913 lb; $\theta_x = 50.6°$, $\theta_y = 117.6°$, $\theta_z = 51.8°$.
2.95 748 N; $\theta_x = 120.1°$, $\theta_y = 52.5°$, $\theta_z = 128.0°$.
2.96 3120 N; $\theta_x = 37.4°$, $\theta_y = 122.0°$, $\theta_z = 72.6°$.
2.97 (*a*) 65.2 lb. (*b*) 208 lb; $\theta_x = 61.6°$, $\theta_y = 151.6°$, $\theta_z = 90.0°$.
2.99 1031 N ↑.
2.101 926 N ↑.
2.103 2100 lb.
2.104 1868 lb.
2.105 1049 lb.
2.107 960 N.
2.108 $0 \le Q < 300$ N.
2.109 1572 lb.
2.111 845 N.
2.112 768 N.
2.113 $T_{AB} = 842$ lb; $T_{AC} = 624$ lb; $T_{AD} = 1088$ lb.
2.114 $T_{AD} = 29.5$ lb; $T_{BD} = 10.25$ lb; $T_{CD} = 29.5$ lb.
2.115 $T_{AB} = 510$ N; $T_{AC} = 56.2$ N; $T_{AD} = 536$ N.
2.116 $T_{AB} = 1340$ N; $T_{AC} = 1025$ N; $T_{AD} = 915$ N.
2.117 $T_{AB} = 1431$ N; $T_{AC} = 1560$ N; $T_{AD} = 183.0$ N.
2.118 $T_{AB} = 1249$ N; $T_{AC} = 490$ N; $T_{AD} = 1647$ N.
2.121 $P = 131.2$ N; $Q = 29.6$ N.
2.123 378 N.
2.125 (*a*) 125.0 lb. (*b*) 45.0 lb.
2.126 $x = 13.42$ in., $z = 6.71$ in.
2.127 37.0°.
2.130 (*a*) 500 lb. (*b*) 544 lb.
2.131 (*a*) 312 N. (*b*) 144 N.
2.133 (*a*) 140.3°. (*b*) $F_x = 79.9$ lb, $F_z = 120.1$ lb; $F = 226$ lb.
2.134 (*a*) −1861 lb, +3360 lb, +677 lb. (*b*) 118.5°, 30.5°, 80.0°.
2.135 15.13 kN; $\theta_x = 133.4°$, $\theta_y = 43.6°$, $\theta_z = 86.6°$.
2.136 $T_{AB} = 500$ N; $T_{AC} = 459$ N; $T_{AD} = 516$ N.

2.137 (*a*) 1155 N. (*b*) 1012 N.
2.C2 (1) (*b*) 20°; (*c*) 244 lb. (2) (*b*) −10°; (*c*) 467 lb. (3) (*b*) 10°; (*c*) 163.2 lb.
2.C3 (*a*) 1.001 m. (*b*) 4.01 kN. (*c*) 1.426 kN; 1.194 kN.

CHAPTER 3

3.1 1.277 N · m ↰.
3.2 1.277 N · m ↰.
3.3 (*a*) 41.7 N · m ↰. (*b*) 147.4 N ∠ 45.0°.
3.4 (*a*) 41.7 N · m ↰. (*b*) 176.8 N ∠ 58.0°.
3.5 186.6 lb · in. ↲.
3.7 6.12° or 33.8°.
3.9 (*a*) 760 N · m ↰. (*b*) 760 N · m ↰.
3.10 1224 N.
3.12 116.2 lb · ft ↰.
3.13 128.2 lb · ft ↰.
3.16 2.21 m.
3.17 (*a*) 41.0. (*b*) 26.9.
3.19 (*a*) $-11\mathbf{i} + 22\mathbf{j} + 22\mathbf{k}$. (*b*) 0. (*c*) $-45\mathbf{i} + 30\mathbf{j} - 10\mathbf{k}$.
3.21 (7.50 N · m)**i** − (6.00 N · m)**j** − (10.39 N · m)**k**.
3.22 (3080 N · m)**i** − (2070 N · m)**k**.
3.24 −(153.0 lb · ft)**i** + (63.0 lb · ft)**j** + (215 lb · ft)**k**.
3.26 (492 lb · ft)**i** + (144.0 lb · ft)**j** − (372 lb · ft)**k**.
3.27 4.58 m.
3.28 3.70 m.
3.30 57.0 in.
3.31 1.564 m.
3.32 3.29 m.
3.33 4.86 ft.
3.35 $\mathbf{P} \cdot \mathbf{Q} = 1$; $\mathbf{P} \cdot \mathbf{S} = -11$; $\mathbf{Q} \cdot \mathbf{S} = 10$.
3.37 27.4°.
3.39 43.6°.
3.40 38.9°.
3.41 (*a*) 59.0°. (*b*) 648 N.
3.43 (*a*) 71.1°. (*b*) 0.973 lb.
3.44 12.00 in.
3.45 (*a*) 67. (*b*) 111.
3.46 7.
3.47 $M_x = -31.2$ N · m; $M_y = 13.20$ N · m; $M_z = -2.42$ N · m.
3.48 $M_x = -25.6$ N · m; $M_y = 10.80$ N · m; $M_z = 40.6$ N · m.
3.49 1.252 m.
3.50 1.256 m.
3.51 61.5 lb.
3.53 $\phi = 24.6°$; $d = 34.6$ in.
3.55 −90.0 N · m.
3.56 −111.0 N · m.
3.57 2.28 N · m.
3.58 −9.50 N · m.
3.59 $aP/\sqrt{2}$.
3.61 1359 lb · in.
3.65 0.249 m.
3.66 0.1198 m.
3.68 30.4 in.
3.69 43.5 in.
3.70 (*a*) 12.39 N · m ↲. (*b*) 12.39 N · m ↲. (*c*) 12.39 N · m ↲.
3.71 (*a*) 336 lb · in. ↰. (*b*) 28.0 in. (*c*) 54.0°.
3.72 (*a*) 75.0 N. (*b*) 71.2 N. (*c*) 45.0 N.
3.75 $M = 10.00$ lb · ft; $\theta_x = 90.0°$, $\theta_y = 143.1°$, $\theta_z = 126.9°$.
3.76 $M = 9.21$ N · m; $\theta_x = 77.9°$, $\theta_y = 12.05°$, $\theta_z = 90.0°$.
3.77 $M = 604$ lb · in.; $\theta_x = 72.8°$, $\theta_y = 27.3°$, $\theta_z = 110.5°$.
3.78 $M = 1170$ lb · in.; $\theta_x = 81.2°$, $\theta_y = 13.70°$, $\theta_z = 100.4°$.
3.79 $M = 10.92$ N · m; $\theta_x = 97.8°$, $\theta_y = 34.5°$, $\theta_z = 56.7°$.
3.80 $M = 2860$ N · m; $\theta_x = 113.0°$, $\theta_y = 92.7°$, $\theta_z = 23.2°$.
3.81 (*a*) **F** = 560 lb ⬎ 20.0°; **M** = 7720 lb · ft ↲.
(*b*) **F** = 560 lb ⬎ 20.0°; **M** = 4290 lb · ft ↲.
3.82 (*a*) **F** = 160.0 lb ∠ 60.0°; **M** = 334 lb · ft ↰.
(*b*) $\mathbf{F}_B$ = 20.0 lb ↑; $\mathbf{F}_D$ = 143.0 lb ∠ 56.0°.
3.83 (*a*) $\mathbf{F}_B$ = 80.0 N ←; $\mathbf{M}_B$ = 4.00 N · m ↰.
(*b*) $\mathbf{F}_C$ = 100.0 N ↓; $\mathbf{F}_D$ = 100.0 N ↑.
3.85 (*a*) $\mathbf{F}_B$ = 250 N ⬎ 60.0°; $\mathbf{M}_B$ = 75.0 N · m ↲.
(*b*) $\mathbf{F}_A$ = 375 N ⬐ 60.0°; $\mathbf{F}_B$ = 625 N ⬎ 60.0°.
3.87 (*a*) **F** = −(600 N)**k**; *d* = 90.0mm below *ED*.
(*b*) **F** = −(600 N)**k**; *d* = 90.0mm above *ED*.
3.88 **F** = 900 N ↓; *x* = 50.0 mm.
3.89 (0.227 lb)**i** + (0.1057 lb)**k**; 63.6 in. to the right of *B*.
3.90 (*a*) **F** = 48.0 lb ∠ 65.0°; **M** = 490 lb · in. ↲.
(*b*) **F** = 48.0 lb ∠ 65.0°; 17.78 in. to the left of *B*.
3.93 **F** = −(1220 N)**i**; **M** = (73.2 N · m)**j** − (122.0 N · m)**k**.
3.94 $\mathbf{F}_C$ = (5.00 N)**i** + (150.0 N)**j** − (90.0 N)**k**;
$\mathbf{M}_C$ = (77.4 N · m)**i** + (61.5 N · m)**j** + (106.8 N · m)**k**.
3.95 **F** = −(128.0 lb)**i** − (256 lb)**j** + (32.0 lb)**k**;
M = (4.10 kip · ft)**i** + (16.38 kip · ft)**k**.
3.97 **F** = −(122.9 N)**j** − (86.0 N)**k**;
M = (22.6 N · m)**i** + (15.49 N · m)**j** − (22.1 N · m)**k**.
3.98 (*a*) 135.0 mm. (*b*) $\mathbf{F}_2$ = (42.0 N)**i** + (42.0 N)**j** − (49.0 N)**k**;
$\mathbf{M}_2$ = −(25.9 N · m)**i** + (21.2 N · m)**j**.
3.99 **F** = (36.0 lb)**i** − (28.0 lb)**j** − (6.00 lb)**k**;
M = −(157.0 lb · ft)**i** + (22.5 lb · ft)**j** − (240 lb · ft)**k**.
3.101 (*a*) *Loading a*: **R** = 600 N ↓; **M** = 1000 N · m ↰.
Loading b: **R** = 600 N ↓; **M** = 900 N · m ↲.
Loading c: **R** = 600 N ↓; **M** = 900 N · m ↰.
Loading d: **R** = 400 N ↑; **M** = 900 N · m ↰.
Loading e: **R** = 600 N ↓; **M** = 200 N · m ↲.
Loading f: **R** = 600 N ↓; **M** = 800 N · m ↰.
Loading g: **R** = 1000 N ↓; **M** = 1000 N · m ↰.
Loading h: **R** = 600 N ↓; **M** = 900 N · m ↰.
(*b*) Loadings *c* and *h*.
3.102 Loading *f*.
3.104 Force-couple system at *D*.
3.105 (*a*) 2.00 ft to the right of *C*. (*b*) 2.31 ft to the right of *C*.
3.106 (*a*) 39.6 in. to the right of *D*. (*b*) 33.1 in.
3.108 **R** = 72.4 lb ⬎ 81.9°; **M** = 206 lb · ft.
3.109 (*a*) 34.0 lb ⬐ 28.0°. (*b*) *AB*: 11.64 in. to the left of *B*; *BC*: 6.20 in. below *B*.
3.110 (*a*) 48.2 lb · in. ↰. (*b*) 240 lb · in. ↰. (*c*) 0.
3.111 (*a*) 1562 N ⬐ 50.2°. (*b*) 250 mm to the right of *C* and 300 mm above *C*.
3.112 (*a*) 1308 N ∠ 66.6°. (*b*) 412 mm to the right of *A* and 250 mm to the right of *C*.
3.113 773 lb ⬏ 79.0°; 9.54 ft to the right of *A*.
3.115 (*a*) 0.365 m above *G*. (*b*) 0.227 m to the right of *G*.
3.116 (*a*) 0.299 m above *G*. (*b*) 0.259 m to the right of *G*.
3.118 (*a*) $\mathbf{R} = F \measuredangle \tan^{-1}(a^2/2bx)$;
$\mathbf{M} = 2Fb^2(x - x^3/a^2)/\sqrt{a^4 + 4b^2x^2}$ ↰. (*b*) 0.369 m.
3.119 **R** = −(420 N)**i** − (50.0 N)**j** − (250 N)**k**;
M = (30.8 N · m)**j** − (22.0 N · m)**k**.
3.120 **R** = −(420 N)**j** − (339 N)**k**;
M = (1.125 N · m)**i** + (163.9 N · m)**j** − (109.9 N · m)**k**.
3.121 (*a*) **B** = (2.50 lb)**i**;
C = (0.1000 lb)**i** − (2.47 lb)**j** − (0.700 lb)**k**.
(*b*) $R_y = -2.47$ lb; $M_x = 1.360$ lb · ft.
3.122 **A** = (1.600 lb)**i** − (36.0 lb)**j** + (2.00 lb)**k**;
B = −(9.60 lb)**i** + (36.0 lb)**j** + (2.00 lb)**k**.

3.124 (*a*) $\mathbf{R} = -(28.4\text{ N})\mathbf{j} - (50.0\text{ N})\mathbf{k}$; $\mathbf{M} = (8.56\text{ N}\cdot\text{m})\mathbf{i} - (24.0\text{ N}\cdot\text{m})\mathbf{j} + (2.13\text{ N}\cdot\text{m})\mathbf{k}$. (*b*) Counterclockwise.
3.125 (*a*) $\mathbf{R} = -(28.4\text{ N})\mathbf{j} - (50.0\text{ N})\mathbf{k}$; $\mathbf{M} = (42.4\text{ N}\cdot\text{m})\mathbf{i} - (24.0\text{ N}\cdot\text{m})\mathbf{j} + (2.13\text{ N}\cdot\text{m})\mathbf{k}$. (*b*) Counterclockwise.
3.127 1035 N; 2.57 m from *OG* and 3.05 m from *OE*.
3.128 2.32 m from *OG* and 1.165 m from *OE*.
3.129 405 lb; 12.60 ft to the right of *AB* and 2.94 ft below *BC*.
3.130 $a = 0.722$ ft; $b = 20.6$ ft.
3.133 (*a*) $P\sqrt{3}$; $\theta_x = \theta_y = \theta_z = 54.7°$. (*b*) $-a$. (*c*) Axis of the wrench is diagonal *OA*.
3.134 (*a*) P; $\theta_x = 90.0°$, $\theta_y = 90.0°$, $\theta_z = 0$. (*b*) $5a/2$. (*c*) Axis of wrench is parallel to the z axis at $x = a$, $y = -a$.
3.136 (*a*) $-(21.0\text{ lb})\mathbf{j}$. (*b*) 0.571 in. (*c*) Axis of wrench is parallel to the y axis at $x = 0$, $z = 1.667$ in.
3.137 (*a*) $-(84.0\text{ N})\mathbf{j} - (80.0\text{ N})\mathbf{k}$. (*b*) 0.477 m. (*c*) $x = 0.526$ m, $z = -0.1857$ m.
3.140 (*a*) $3P(2\mathbf{i} - 20\mathbf{j} - \mathbf{k})/25$. (*b*) $-0.0988a$. (*c*) $x = 2.00a$, $z = -1.990a$.
3.141 $\mathbf{R} = (20.0\text{ N})\mathbf{i} + (30.0\text{ N})\mathbf{j} - (10.00\text{ N})\mathbf{k}$; $y = -0.540$ m, $z = -0.420$ m.
3.143 $\mathbf{F}_A = (M/b)\mathbf{i} + R[1 + (a/b)]\mathbf{k}$; $\mathbf{F}_B = -(M/b)\mathbf{i} - (aR/b)\mathbf{k}$.
3.147 (*a*) 196.2 N · m ⤓. (*b*) 199.0 N ⬊ 59.5°.
3.148 42.0 N · m ↰.
3.149 $-(25.4\text{ lb}\cdot\text{ft})\mathbf{i} - (12.60\text{ lb}\cdot\text{ft})\mathbf{j} - (12.60\text{ lb}\cdot\text{ft})\mathbf{k}$.
3.151 283 lb.
3.153 (*a*) 151.2 lb · in. ↰. (*b*) 67.2 lb · in. ↰.
3.155 $\mathbf{F} = -(28.5\text{ N})\mathbf{j} + (106.3\text{ N})\mathbf{k}$; $\mathbf{M} = (12.35\text{ N}\cdot\text{m})\mathbf{i} - (19.16\text{ N}\cdot\text{m})\mathbf{j} - (5.13\text{ N}\cdot\text{m})\mathbf{k}$.
3.156 (*a*) 665 lb ⬈ 79.6°; 64.9 in. to the right of *A*. (*b*) 22.9°.
3.157 (*a*) $\mathbf{F}_B = -(80.0\text{ N})\mathbf{k}$; $\mathbf{F}_C = -(30.0\text{ N})\mathbf{i} + (40.0\text{ N})\mathbf{k}$. (*b*) $R_y = 0$; $R_z = -40.0$ N. (*c*) When the slot is vertical.
3.C3 *4 sides*: $\beta = 10°$, $\alpha = 44.1°$; $\beta = 20°$, $\alpha = 41.6°$; $\beta = 30°$, $\alpha = 37.8°$.
3.C4 $\theta = 0$ *rev*: $M = 97.0$ N · m; $\theta = 6$ *rev*: $M = 63.3$ N · m; $\theta = 12$ *rev*: $M = 9.17$ N · m.
3.C6 $d_{AB} = 36.0$ in.; $d_{CD} = 9.00$ in.; $d_{\min} = 58.3$ in.

CHAPTER 4

4.1 (*a*) 325 lb ↑. (*b*) 1175 lb ↑.
4.2 42.0 N ↑
4.3 0.264 m
4.4 (*a*) 245 lb. ↑. (*b*) 140.0 lb.
4.5 (*a*) 6.07 kN ↑. (*b*) 4.23 kN ↑.
4.6 (*a*) 4.89 kN ↑. (*b*) 3.69 kN ↑.
4.9 150.0 mm ≤ d ≤ 400 mm.
4.11 6.00 kips ≤ P ≤ 42.0 kips.
4.12 3.50 kN ≤ P ≤ 86.0 kN.
4.14 2.00 in. ≤ a ≤ 10.00 in.
4.15 (*a*) $F_{DE} = 600$ N. (*b*) $\mathbf{C} = 1253$ N ⬈ 69.8°.
4.17 (*a*) 80.0 lb ↓. (*b*) 216 lb ⬈ 22.0°.
4.18 232 lb.
4.19 (*a*) 2.00 kN. (*b*) 2.32 kN ⬈ 46.4°.
4.21 (*a*) $\mathbf{A} = 150.0$ N ⬈ 30.0°; $\mathbf{B} = 150.0$ N ⬊ 30.0°. (*b*) $\mathbf{A} = 433$ N ⬉ 12.55°; $\mathbf{B} = 488$ N ⬊ 30.0°.
4.23 (*a*) $\mathbf{A} = 44.7$ lb ⬊ 26.6°; $\mathbf{B} = 30.0$ lb ↑. (*b*) $\mathbf{A} = 30.2$ lb ⬊ 41.4°; $\mathbf{B} = 34.6$ lb ⬊ 60.0°.
4.24 (*a*) $\mathbf{A} = 20.0$ lb ↑; $\mathbf{B} = 50.0$ lb ⬊ 36.9°. (*b*) $\mathbf{A} = 23.1$ lb ⬈ 60.0°; $\mathbf{B} = 59.6$ lb ⬊ 30.2°.
4.26 (*a*) 190.9 N. (*b*) 142.3 N ⬈ 18.43°.
4.27 (*a*) 324 N. (*b*) 270 N →.
4.28 (*a*) 400 N. (*b*) $\mathbf{C} = 458$ N ⬈ 49.1°.
4.29 (*a*) 875 lb (*b*) 1584 lb ⬊ 45.0°.
4.30 $T = 80.0$ N; $\mathbf{C} = 89.4$ N ⬈ 26.6°.
4.33 $T = 2P/3$; $\mathbf{C} = 0.577P$ →.
4.34 $T = 0.586P$; $\mathbf{C} = 0.414P$ →.
4.35 $\mathbf{A} = 69.3$ lb →; $\mathbf{B} = 34.6$ lb ⬉ 60.0°; $\mathbf{C} = 173.2$ lb ⬊ 60.0°.
4.36 $T_{BE} = 50.0$ lb; $\mathbf{A} = 18.75$ lb →; $\mathbf{D} = 18.75$ lb ←.
4.37 (*a*) 1432 N. (*b*) 1100 N ↑. (*c*) 1400 N ←.
4.38 $T_{BE} = 3230$ N; $T_{CF} = 960$ N; $\mathbf{D} = 3750$ N ←.
4.41 $T = 80.0$ N; $\mathbf{A} = 160.0$ N ⬉ 30.0°; $\mathbf{C} = 160.0$ N ⬊ 30.0°.
4.42 $T = 69.3$ N; $\mathbf{A} = 140.0$ N ⬉ 30.0°; $\mathbf{C} = 180.0$ N ⬊ 30.0°.
4.43 (*a*) $\mathbf{A} = 78.5$ N; $\mathbf{M}_A = 125.6$ N · m ↰. (*b*) $\mathbf{A} = 111.0$ N ⬈ 45.0°; $\mathbf{M}_A = 125.6$ N · m ↰. (*c*) $\mathbf{A} = 157.0$ N ↑; $\mathbf{M}_A = 251$ N · m ↰.
4.44 $\mathbf{C} = 7.07$ lb ⬊ 45.0°; $\mathbf{M}_C = 43.0$ lb · in. ⤓.
4.46 $\mathbf{A} = 1848$ N ⬈ 82.6°; $\mathbf{M}_A = 1431$ N · m ⤓.
4.47 (*a*) $\mathbf{D} = 20.0$ lb ↓; $\mathbf{M}_D = 20.0$ lb · ft ↰. (*b*) $\mathbf{D} = 10.00$ lb ↓; $\mathbf{M}_D = 30.0$ lb · ft ⤓.
4.49 $\mathbf{C} = 1951$ N ⬊ 88.5°; $\mathbf{M}_C = 75.0$ N · m ⤓.
4.50 1.232 kN ≤ T ≤ 1.774 kN.
4.51 (*a*) $\theta = 2\sin^{-1}(W/2P)$. (*b*) $\theta = 29.0°$.
4.52 (*a*) $T = \frac{1}{2}W/(1 - \tan\theta)$. (*b*) $\theta = 39.8°$.
4.53 (*a*) $\sin\theta + \cos\theta = M/Pl$. (*b*) 17.11° and 72.9°.
4.54 (*a*) $\cos^3\theta = a(P + Q)/Pl$. (*b*) 40.6°.
4.57 141.1°
4.58 (*a*) $(1 - \cos\theta)\tan\theta = W/2kl$. (*b*) 49.7°.
4.59 (1) completely constrained; determinate; $\mathbf{A} = \mathbf{C} = 196.2$ N ↑.
(2) completely constrained; determinate; $\mathbf{B} = 0$, $\mathbf{C} = \mathbf{D} = 196.2$ N ↑.
(3) completely constrained; indeterminate; $\mathbf{A}_x = 294$ N →; $\mathbf{D}_x = 294$ N ←.
(4) improperly constrained; indeterminate; no equilibrium.
(5) partially constrained; determinate; equilibrium; $\mathbf{C} = \mathbf{D} = 196.2$ N ↑.
(6) completely constrained; determinate; $\mathbf{B} = 294$ N →, $\mathbf{D} = 491$ N ⬊ 53.1°.
(7) partially constrained; no equilibrium.
(8) completely constrained; indeterminate; $\mathbf{B} = 196.2$ N ↑, $\mathbf{D}_y = 196.2$ N ↑.
4.61 $\mathbf{A} = 400$ N ↑; $\mathbf{B} = 500$ N ⬉ 53.1°.
4.62 $a \geq 138.6$ mm.
4.66 $\mathbf{B} = 888$ N ⬉ 41.3°; $\mathbf{D} = 943$ N ⬊ 45.0°.
4.67 $\mathbf{B} = 1001$ N ⬊ 48.2°; $\mathbf{D} = 943$ N ⬉ 45.0°.
4.69 (*a*) 499 N. (*b*) 457 N ⬊ 26.6°.
4.70 (*a*) 998 N. (*b*) 822 N ⬋ 5.72°.
4.71 $\mathbf{A} = 37.1$ lb ⬈ 62.4°; $T = 18.57$ lb.
4.74 (*a*) 24.9 lb ⬋ 30.0°. (*b*) 15.34 lb ⬈ 30.0°.
4.75 $T = 100.0$ lb; $\mathbf{B} = 111.1$ lb ⬉ 30.3°.
4.77 $\mathbf{A} = 170.0$ N ⬊ 33.9°; $\mathbf{C} = 160.0$ N ⬈ 28.1°.
4.80 (*a*) $F_{AD} = 400$ N. (*b*) $\mathbf{C} = 458$ N ⬈ 49.1°.
4.81 (*a*) $2P$ ⬊ 60.0°. (*b*) $1.239P$ ⬉ 36.2°.
4.82 (*a*) $1.155P$ ⬊ 30.0°. (*b*) $1.086P$ ⬈ 22.9°.
4.83 60.0 mm.
4.84 $\tan\theta = 2\tan\beta$.
4.85 (*a*) 49.1°. (*b*) $\mathbf{A} = 45.3$ N ←; $\mathbf{B} = 90.6$ N ⬈ 60.0°.
4.87 (*a*) 12.91 in. (*b*) 11.62 lb. (*c*) 5.92 lb.
4.88 32.5°.
4.90 (*a*) 59.4°. (*b*) $\mathbf{A} = 8.45$ lb →; $\mathbf{B} = 13.09$ lb ⬊ 49.8°.

4.91 $\mathbf{A} = (22.9\text{ lb})\mathbf{i} + (8.50\text{ lb})\mathbf{j}$; $\mathbf{B} = (22.9\text{ lb})\mathbf{i} + (25.5\text{ lb})\mathbf{j}$; $\mathbf{C} = -(45.8\text{ lb})\mathbf{i}$.
4.92 $\mathbf{A} = (56.0\text{ N})\mathbf{j} + (18.00\text{ N})\mathbf{k}$; $\mathbf{D} = (24.0\text{ N})\mathbf{j} + (42.0\text{ N})\mathbf{k}$.
4.93 $\mathbf{A} = (56.0\text{ N})\mathbf{j} + (14.40\text{ N})\mathbf{k}$; $\mathbf{D} = (24.0\text{ N})\mathbf{j} + (33.6\text{ N})\mathbf{k}$.
4.94 (*a*) 37.5 lb. (*b*) $\mathbf{B} = (33.8\text{ lb})\mathbf{j} - (70.0\text{ lb})\mathbf{k}$; $\mathbf{D} = (33.8\text{ lb})\mathbf{j} + (28.0\text{ lb})\mathbf{k}$.
4.97 (*a*) 121.9 N. (*b*) −46.2 N. (*c*) 100.9 N.
4.98 (*a*) 95.6 N. (*b*) −7.36 N. (*c*) 88.3 N.
4.99 $T_A = 30.0$ lb; $T_B = 10.00$ lb; $T_C = 40.0$ lb.
4.100 $(W_D)_{\min} = 40.0$ lb; $x = 0$ in.; $z = 30.0$ in.
4.101 $T_A = 23.5$ N; $T_C = 11.77$ N; $T_D = 105.9$ N.
4.102 (*a*) 0.480 m. (*b*) $T_A = 23.5$ N; $T_C = 0$; $T_D = 117.7$ N.
4.105 $T_{BD} = T_{BE} = 1100$ lb; $\mathbf{A} = (1200\text{ lb})\mathbf{i} - (560\text{ lb})\mathbf{j}$.
4.106 $T_{AD} = 2.60$ kN; $T_{AE} = 2.80$ kN; $\mathbf{C} = (1.800\text{ kN})\mathbf{j} + (4.80\text{ kN})\mathbf{k}$.
4.107 $T_{AD} = 5.20$ kN; $T_{AE} = 5.60$ kN; $\mathbf{C} = (9.60\text{ kN})\mathbf{k}$.
4.108 (*a*) $T_{DE} = T_{DF} = 262$ lb. (*b*) $\mathbf{A} = -(801\text{ lb})\mathbf{i} + (1544\text{ lb})\mathbf{j}$.
4.109 (*a*) $T_{CD} = T_{CE} = 3.96$ kN. (*b*) $\mathbf{A} = (6.67\text{ kN})\mathbf{i} + (1.667\text{ kN})\mathbf{j}$.
4.110 (*a*) $T_{CD} = 0.954$ kN; $T_{CE} = 5.90$ kN.
(*b*) $\mathbf{A} = (5.77\text{ kN})\mathbf{i} + (1.443\text{ kN})\mathbf{j} - (0.833\text{ kN})\mathbf{k}$.
4.113 (*a*) 101.6 N. (*b*) $\mathbf{A} = -(26.3\text{ N})\mathbf{i}$; $\mathbf{B} = (98.1\text{ N})\mathbf{j}$.
4.114 (*a*) 462 N. (*b*) $\mathbf{C} = -(336\text{ N})\mathbf{j} + (467\text{ N})\mathbf{k}$; $\mathbf{D} = (505\text{ N})\mathbf{j} - (66.7\text{ N})\mathbf{k}$.
4.117 (*a*) 49.5 lb. (*b*) $\mathbf{A} = -(12.00\text{ lb})\mathbf{i} + (22.5\text{ lb})\mathbf{j} - (4.00\text{ lb})\mathbf{k}$; $\mathbf{B} = (15.00\text{ lb})\mathbf{j} + (34.0\text{ lb})\mathbf{k}$.
4.118 (*a*) 118.8 lb. (*b*) $\mathbf{A} = (93.8\text{ lb})\mathbf{i} + (22.5\text{ lb})\mathbf{j} + (70.8\text{ lb})\mathbf{k}$; $\mathbf{B} = (15.00\text{ lb})\mathbf{j} - (8.33\text{ lb})\mathbf{k}$.
4.119 (*a*) 462 N. (*b*) $\mathbf{C} = (169.1\text{ N})\mathbf{j} + (400\text{ N})\mathbf{k}$; $\mathbf{M}_C = (20.0\text{ N}\cdot\text{m})\mathbf{j} + (151.5\text{ N}\cdot\text{m})\mathbf{k}$.
4.120 (*a*) 49.5 lb. (*b*) $\mathbf{A} = -(12.00\text{ lb})\mathbf{i} + (37.5\text{ lb})\mathbf{j} + (30.0\text{ lb})\mathbf{k}$; $\mathbf{M}_A = -(1020\text{ lb}\cdot\text{in.})\mathbf{j} + (450\text{ lb}\cdot\text{in.})\mathbf{k}$.
4.121 (*a*) 5.00 lb. (*b*) $\mathbf{C} = -(5.00\text{ lb})\mathbf{i} + (6.00\text{ lb})\mathbf{j} - (5.00\text{ lb})\mathbf{k}$; $\mathbf{M}_C = (8.00\text{ lb}\cdot\text{in.})\mathbf{j} - (12.00\text{ lb}\cdot\text{in.})\mathbf{k}$.
4.122 $T_{CF} = 200$ N; $T_{DE} = 450$ N; $\mathbf{A} = (160.0\text{ N})\mathbf{i} + (270\text{ N})\mathbf{k}$; $\mathbf{M}_A = -(16.20\text{ N}\cdot\text{m})\mathbf{i}$.
4.125 $T_{BE} = 975$ N; $T_{CF} = 600$ N; $T_{DG} = 625$ N; $\mathbf{A} = (2100\text{ N})\mathbf{i} + (175.0\text{ N})\mathbf{j} - (375\text{ N})\mathbf{k}$.
4.126 $T_{BE} = 1950$ N; $T_{CF} = 0$; $T_{DG} = 1250$ N; $\mathbf{A} = (3000\text{ N})\mathbf{i} - (750\text{ N})\mathbf{k}$.
4.127 $\mathbf{A} = (120.0\text{ lb})\mathbf{j} - (150.0\text{ lb})\mathbf{k}$; $\mathbf{B} = (180.0\text{ lb})\mathbf{i} + (150.0\text{ lb})\mathbf{k}$; $\mathbf{C} = -(180.0\text{ lb})\mathbf{i} + (120.0\text{ lb})\mathbf{j}$.
4.128 $\mathbf{A} = (20.0\text{ lb})\mathbf{j} + (25.0\text{ lb})\mathbf{k}$; $\mathbf{B} = (30.0\text{ lb})\mathbf{i} - (25.0\text{ lb})\mathbf{k}$; $\mathbf{C} = -(30.0\text{ lb})\mathbf{i} - (20.0\text{ lb})\mathbf{j}$.
4.129 $\mathbf{B} = (60.0\text{ N})\mathbf{k}$; $\mathbf{C} = (30.0\text{ N})\mathbf{j} - (16.00\text{ N})\mathbf{k}$; $\mathbf{D} = -(30.0\text{ N})\mathbf{j} + (4.00\text{ N})\mathbf{k}$.
4.130 $\mathbf{B} = (60.0\text{ N})\mathbf{k}$; $\mathbf{C} = -(16.00\text{ N})\mathbf{k}$; $\mathbf{D} = (4.00\text{ N})\mathbf{k}$.
4.133 85.3 lb.
4.134 181.7 lb.
4.135 373 N
4.136 301 N
4.137 $(45.0\text{ lb})\mathbf{j}$
4.138 (*a*) $x = 4.00$ ft; $y = 8.00$ ft. (*b*) 10.73 lb.
4.139 (*a*) $x = 0$ ft; $y = 16.00$ ft. (*b*) 11.31 lb.
4.142 (*a*) 37.9 N ↑. (*b*) 373 N ↑.
4.143 (*a*) $\mathbf{A} = 225$ N ↑; $\mathbf{C} = 641$ N ◸ 20.6°.
(*b*) $\mathbf{A} = 365$ N ◿ 60.0°; $\mathbf{B} = 844$ N ◸ 22.0°.
4.145 (*a*) 130.0 N, (*b*) 224 N ◸ 2.05°.
4.146 $\mathbf{C} = 7.97$ lb →; $\mathbf{D} = 42.6$ lb ←; $\mathbf{E} = 69.3$ lb ◿ 60.0°.
4.148 $\mathbf{A} = 63.6$ lb ◹ 45.0°; $\mathbf{C} = 87.5$ lb ◺ 59.0°.
4.150 $T_{BD} = 780$ N; $T_{BE} = 390$ N; $\mathbf{A} = -(195.0\text{ N})\mathbf{i} + (1170\text{ N})\mathbf{j} + (130.0\text{ N})\mathbf{k}$.
4.152 $T_{FJ} = 0$; $T_{DH} = 60.0$ lb; $T_{BG} = 80.0$ lb; $\mathbf{A} = (100.0\text{ lb})\mathbf{i} - (48.0\text{ lb})\mathbf{k}$.
4.153 (*a*) $\mathbf{A} = 0.745P$ ◿ 63.4°; $\mathbf{C} = 0.471P$ ◺ 45.0°.
(*b*) $\mathbf{A} = 0.812P$ ◿ 60.0°; $\mathbf{C} = 0.503P$ ◸ 36.2°.
(*c*) $\mathbf{A} = 0.448P$ ◺ 60.0°; $\mathbf{C} = 0.652P$ ◿ 69.9°.
(*d*) improperly constrained; no equilibrium.
4.C1 $\theta = 20°$: $T = 114.8$ lb; $\theta = 70°$: $T = 127.7$ lb; $T_{\max} = 132.2$ lb at $\theta = 50.4°$.
4.C2 $x = 600$ *mm*: $P = 31.4$ N; $x = 150$ *mm*: $P = 37.7$ N; $P_{\max} = 47.2$ N at $x = 283$ mm.
4.C3 $\theta = 30°$: $W = 9.66$ lb; $\theta = 60°$: $W = 36.6$ lb; $W = 5$ lb at $\theta = 22.9°$ [Also at $\theta = 175.7°$].
4.C4 $\theta = 30°$: $W = 0.80$ lb; $\theta = 60°$: $W = 4.57$ lb; $W = 5$ lb at $\theta = 62.6°$ [Also at $\theta = 159.6°$].
4.C5 $\theta = 30°$: $m = 7.09$ kg; $\theta = 60°$: $m = 11.02$ kg. When $m = 10$ kg, $\theta = 51.0°$.
4.C6 $\theta = 15°$: $T_{BD} = 10.30$ kN, $T_{BE} = 21.7$ kN; $\theta = 30°$: $T_{BD} = 5.69$ kN, $T_{BE} = 24.4$ kN; $T_{\max} = 26.5$ kN at $\theta = 36.9°$.

CHAPTER 5

5.1 $\overline{X} = 175.6$ mm, $\overline{Y} = 94.4$ mm.
5.2 $\overline{X} = 16.21$ mm, $Y = 31.9$ mm.
5.3 $\overline{X} = 19.28$ in., $\overline{Y} = 6.94$ in.
5.4 $\overline{X} = 5.67$ in., $\overline{Y} = 5.17$ in.
5.5 $\overline{X} = 7.22$ in., $Y = 9.56$ in.
5.6 $\overline{X} = 92.0$ mm, $\overline{Y} = 23.3$ mm.
5.9 $\overline{X} = -10.00$ mm, $\overline{Y} = 87.5$ mm.
5.10 $\overline{X} = -9.89$ mm, $\overline{Y} = -10.67$ mm
5.11 $\overline{X} = 0$, $\overline{Y} = 6.45$ in.
5.12 $\overline{X} = 50.5$ mm, $\overline{Y} = 19.34$ mm.
5.14 $\overline{X} = \overline{Y} = 9.00$ in.
5.16 $\overline{Y} = \dfrac{2}{3}\left(\dfrac{r_2^3 - r_1^3}{r_2^2 - r_1^2}\right)\left(\dfrac{2\cos\alpha}{\pi - 2\alpha}\right)$
5.17 $\overline{Y} = \dfrac{r_1 + r_2}{\pi - 2\alpha}\cos\alpha$
5.18 $a/b = 4/5$
5.20 459 N
5.21 $(Q_x)_1 = 25.0\text{ in}^3$; $(Q_x)_2 = -25.0\text{ in}^3$.
5.22 $(Q_x)_1 = 23.3\text{ in}^3$; $(Q_x)_2 = -23.3\text{ in}^3$.
5.24 $\overline{X} = 172.5$ mm, $\overline{Y} = 97.5$ mm
5.26 $\overline{X} = 18.45$ in., $\overline{Y} = 6.48$ in.
5.28 (*a*) $T = 5.09$ lb. (*b*) $\mathbf{C} = 9.48$ lb ◺ 57.5°.
5.29 0.739 m
5.30 $L = 0.204$ m or 0.943 m
5.32 (*a*) $h = 0.513a$. (*b*) $h = 0.691a$
5.34 $\bar{x} = 2/3a$, $\bar{y} = \frac{1}{3}h$.
5.35 $\bar{x} = a/2$, $\bar{y} = 2h/5$.
5.37 $\bar{x} = 2a/3(4 - \pi)$, $\bar{y} = 2b/3(4 - \pi)$
5.39 $\bar{x} = a(3 - 4\sin\alpha)/6(1 - \alpha)$, $\bar{y} = 0$.
5.40 $\bar{x} = a/4$, $\bar{y} = 3b/10$.
5.41 $\bar{x} = 5a/8$, $\bar{y} = b/3$.
5.42 $\bar{x} = 5L/4$, $\bar{y} = 33a/40$.
5.44 $\bar{x} = a$, $\bar{y} = 17b/35$.
5.45 $2/5a$
5.46 $-2\sqrt{2}r/3\pi$.
5.48 $\bar{x} = 0.236L$, $\bar{y} = 0.454a$.
5.49 $\bar{x} = -9.27a$, $\bar{y} = 3.09a$.
5.50 $\bar{x} = 1.629$ in., $\bar{y} = 0.1853$ in.
5.51 $a = 1.901$ in. or 3.74 in.

5.52 (*a*) $V = 6.19 \times 10^6$ mm^3; $A = 458 \times 10^3$ mm^2.
(*b*) $V = 16.88 \times 10^6$ mm^3; $A = 1.171 \times 10^6$ mm^2.
5.53 (*a*) $V = 308 \times 10^3$ mm^3; $A = 38.2 \times 10^3$ mm^2.
(*b*) $V = 177.2 \times 10^3$ mm^3; $A = 22.4 \times 10^3$ mm^2.
5.54 (*a*) $V = 169.0 \times 10^3$ in^3; $A = 28.4 \times 10^3$ in^2.
(*b*) $V = 88.9 \times 10^3$ in^3; $A = 15.48 \times 10^3$ in^2.
5.56 $V = 3470$ mm^3; $A = 2320$ mm^2.
5.58 $V = 0.0900$ in^3.
5.59 $V = 31.9$ liters.
5.61 $m = 0.0305$ kg.
5.63 22.0 gallons
5.64 66.5%
5.66 (*a*) $\mathbf{R} = 1215$ lb $\downarrow$, $\bar{x} = 4.33$ ft.
(*b*) $\mathbf{A} = 630$ lb $\uparrow$; $\mathbf{B} = 585$ lb $\uparrow$
5.67 (*a*) $\mathbf{R} = 2400$ N $\downarrow$, 2.33 m to the right of *A*.
(*b*) $\mathbf{A} = 1000$ N $\uparrow$; $\mathbf{B} = 1400$ N $\uparrow$.
5.68 $\mathbf{A} = 32.0$ kN; $\mathbf{M}_A = 124.0$ kN · m $\circlearrowleft$.
5.69 $\mathbf{B} = 1360$ lb $\uparrow$; $\mathbf{C} = 2360$ lb $\uparrow$.
5.71 $\mathbf{A} = 480$ N $\uparrow$; $\mathbf{B} = 840$ N $\downarrow$.
5.73 $\mathbf{A} = 3000$ N $\uparrow$; $\mathbf{M}_A = 12.60$ kN · m $\circlearrowleft$.
5.74 (*a*) $a = 0.536$ m. (*b*) $\mathbf{A} = \mathbf{B} = 761$ N $\uparrow$.
5.76 $\mathbf{B} = 150.0$ lb $\uparrow$; $\mathbf{C} = 5250$ lb $\uparrow$.
5.77 (*a*) $w_0 = 100.0$ lb/ft. (*b*) $\mathbf{C} = 4950$ lb $\uparrow$.
5.78 $w_A = 10.00$ kN/m; $w_B = 50.0$ kN/m.
5.80 (*a*) $\mathbf{H} = 254$ kN $\rightarrow$; $\mathbf{V} = 831$ kN $\uparrow$.
(*b*) $x = 3.25$ m to the right of *A*.
(*c*) $\mathbf{R} = 268$ kN $\measuredangle$ 18.43°.
5.81 (*a*) $\mathbf{H} = 13.76$ kips $\rightarrow$; $\mathbf{V} = 113.0$ kips $\uparrow$.
(*b*) 22.4 ft to the right of *A*.
(*c*) $\mathbf{R} = 25.6$ kips $\measuredangle$ 57.5°.
5.82 $d = 2.64$ m.
5.83 $\mathbf{T} = 67.2$ kN $\leftarrow$; $\mathbf{A} = 141.2$ kN $\leftarrow$.
5.84 $\mathbf{T} = 3.70$ kips $\uparrow$.
5.85 $d = 5.88$ ft.
5.88 $\mathbf{A} = 1197$ N $\measuredangle$ 53.1°; $\mathbf{B} = 1511$ N $\measuredangle$ 53.1°.
5.89 $T = 3570$ N.
5.90 $T = 208$ lb
5.91 $d = 6.00$ ft.
5.93 $d = 0.683$ m
5.94 $h = 0.0711$ m
5.96 (*a*) $b/10$ to the left of base of cone.
(*b*) $0.01136b$ to the right of base of cone.
5.97 $\bar{Y} = -(2h^2 - 3b^2)/2(4h - 3b)$.
5.98 $\bar{Z} = -a(4h - 2b)/\pi(4h - 3b)$.
5.99 (*a*) $\bar{Y} = -0.402a$. (*b*) $h/a = 2/5$ or $2/3$.
5.100 $\bar{X} = 46.8$ mm.
5.101 $\bar{Z} = 26.2$ mm.
5.103 $\bar{Y} = -0.1403$ in.
5.104 $\bar{Z} = 3.47$ in.
5.106 $\bar{X} = 0.295$ m, $\bar{Y} = 0.423$ m, $\bar{Z} = 1.703$ m.
5.107 $\bar{X} = 125.0$ mm, $\bar{Y} = 167.0$ mm, $\bar{Z} = 33.5$ mm.
5.108 $\bar{X} = \bar{Z} = 4.21$ in., $\bar{Y} = 7.03$ in.
5.110 $\bar{X} = 46.5$ mm, $\bar{Y} = 27.2$ mm, $\bar{Z} = 30.0$ mm
5.111 $\bar{X} = 17.00$ in., $\bar{Y} = 15.68$ in., $\bar{Z} = 14.16$ in.
5.112 $\bar{X} = 180.2$ mm, $\bar{Y} = 38.0$ mm, $\bar{Z} = 193.5$ mm.
5.114 $\bar{X} = 0.1452$ m, $\bar{Y} = 0.396$ m, $\bar{Z} = 0.370$ m.
5.115 $\bar{X} = 0.410$ m, $\bar{Y} = 0.510$ m, $\bar{Z} = 0.1500$ m.
5.117 $\bar{X} = 1.750$ ft, $\bar{Y} = 4.14$ ft, $\bar{Z} = 1.355$ ft.
5.118 $\bar{X} = 61.6$ mm from the end of the handle.
5.119 $\bar{Y} = 0.526$ in. above the base.
5.121 $\bar{Y} = 421$ mm. above the floor.
5.122 $(\bar{x})_1 = 21a/88$; $(\bar{x})_2 = 27a/40$.
5.123 $(\bar{x})_1 = 21h/88$; $(\bar{x})_2 = 27h/40$.
5.124 $(\bar{x})_1 = 2h/9$; $(\bar{x})_2 = 2h/3$.
5.125 $\bar{x} = h/6$; $\bar{y} = \bar{z} = 0$.
5.128 $\bar{x} = 1.297a$, $\bar{y} = \bar{z} = 0$.
5.129 $\bar{x} = \bar{z} = 0$, $\bar{y} = 0.374h$.
5.132 (*a*) $\bar{x} = \bar{z} = 0$, $\bar{y} = -121.9$ mm.
(*b*) $\bar{x} = \bar{z} = 0$, $\bar{y} = -90.2$ mm.
5.133 $V = 688$ ft^3; $\bar{x} = 15.91$ ft.
5.134 $\bar{x} = a/2$, $\bar{y} = 8h/25$, $\bar{z} = b/2$.
5.136 $\bar{x} = 0$, $\bar{y} = 5h/16$, $\bar{z} = -b/4$.
5.137 $\bar{X} = 19.27$ mm, $\bar{Y} = 26.6$ mm.
5.138 $\bar{X} = 3.20$ in., $\bar{Y} = 2.00$ in.
5.140 $\bar{x} = a/2$, $\bar{y} = 3h/5$.
5.141 $\bar{x} = 3a/8$, $\bar{y} = b$.
5.143 $\mathbf{A} = 1300$ N $\uparrow$; $\mathbf{B} = 1850$ N $\uparrow$.
5.146 (*a*) $\bar{x} = 0.548L$. (*b*) $h/L = 2\sqrt{3}$.
5.147 $\bar{X} = 0.1402$ m, $\bar{Y} = 0.0944$ m, $\bar{Z} = 0.0959$ m.
5.148 $\bar{x} = 2.34$ m, $\bar{y} = \bar{z} = 0$.
5.C1 (*b*) $\mathbf{A} = 1220$ lb $\uparrow$; $\mathbf{B} = 1830$ lb $\uparrow$.
(*c*) $\mathbf{A} = 1265$ lb $\uparrow$; $\mathbf{B} = 1601$ lb $\uparrow$.
5.C2 (*a*) $\bar{X} = 0$, $\bar{Y} = 0.278$ m, $\bar{Z} = 0.0878$ m.
(*b*) $\bar{X} = 0.0487$ mm, $\bar{Y} = 0.1265$ mm, $\bar{Z} = 0.0997$ mm.
(*c*) $\bar{X} = -0.0372$ m, $\bar{Y} = 0.1659$ m, $\bar{Z} = 0.1043$ m.
5.C3 *d = 1.00 m*: $\mathbf{F} = 5.66$ kN $\measuredangle$ 30°;
d = 3.00 m: $\mathbf{F} = 49.9$ kN $\measuredangle$ 27.7°.
5.C4 (*a*) $\bar{X} = 5.80$ in., $\bar{Y} = 1.492$ in. (*b*) $\bar{X} = 9.11$ in., $\bar{Y} = 2.78$ in.
(*c*) $\bar{X} = 8.49$ in., $\bar{Y} = 0.375$ in.
5.C5 *With n = 40*: (*a*) $\bar{X} = 60.2$ mm, $\bar{Y} = 23.4$ mm.
(*b*) $\bar{X} = 60.2$ mm, $\bar{Y} = 146.2$ mm.
(*c*) $\bar{X} = 68.7$ mm. $\bar{Y} = 20.4$ mm.
(*d*) $\bar{X} = 68.7$ mm, $\bar{Y} = 127.8$ mm.
5.C6 *With n = 40*: (*a*) $\bar{X} = 60.0$ mm, $\bar{Y} = 24.0$ mm.
(*b*) $\bar{X} = 60.0$ mm, $\bar{Y} = 150.0$ mm.
(*c*) $\bar{X} = 68.6$ mm, $\bar{Y} = 21.8$ mm.
(*d*) $\bar{X} = 68.6$ mm, $\bar{Y} = 136.1$ mm.
5.C7 (*a*) $V = 628$ ft^3.
(*b*) $\bar{X} = 8.65$ ft, $\bar{Y} = -4.53$ ft, $\bar{Z} = 9.27$ ft.

CHAPTER 6

6.1 $F_{AB} = 52.0$ kN *T*; $F_{AC} = 64.0$ kN *T*; $F_{BC} = 80.0$ kN *C*.
6.2 $F_{AB} = 375$ lb *C*; $F_{AC} = 780$ lb *C*; $F_{BC} = 300$ lb *T*.
6.3 $F_{AB} = 4.00$ kN *C*; $F_{AC} = 2.72$ kN *T*; $F_{BC} = 2.40$ kN *C*.
6.5 $F_{AB} = F_{BC} = 31.5$ kips *T*; $F_{AD} = 35.7$ kips *C*;
$F_{BD} = 10.80$ kips *C*; $F_{CD} = 33.3$ kips *C*.
6.6 $F_{AB} = F_{BD} = 0$; $F_{AC} = 675$ N *T*; $F_{AD} = 1125$ N *C*;
$F_{CD} = 900$ N *T*; $F_{CE} = 2025$ N *T*; $F_{CF} = 2250$ N *C*;
$F_{DF} = 675$ N *C*; $F_{EF} = 1800$ N *T*.
6.7 $F_{AB} = 15.90$ kN *C*; $F_{AC} = 13.50$ kN *T*; $F_{BC} = 16.80$ kN *C*;
$F_{BD} = 13.50$ kN *C*; $F_{CD} = 15.90$ kN *T*.
6.9 $F_{AB} = 47.2$ kN *C*; $F_{AC} = 44.6$ kN *T*; $F_{BC} = 10.50$ kN *C*;
$F_{BD} = 47.2$ kN *C*; $F_{CD} = 17.50$ kN *T*; $F_{CE} = 30.6$ kN *T*;
$F_{DE} = 0$.
6.10 $F_{AB} = F_{HI} = 12.31$ kN *C*; $F_{AC} = F_{GI} = 11.25$ kN *T*; $F_{BC} =$
$F_{GH} = 2.46$ kN *C*; $F_{BD} = F_{DE} = F_{EF} = F_{FH} = 9.85$ kN *C*;
$F_{CD} = F_{FG} = 2.00$ kN *C*; $F_{CE} = F_{EG} = 3.75$ kN *T*;
$F_{CG} = 6.75$ kN *T*.
6.11 $F_{AB} = F_{FH} = 1500$ lb *C*; $F_{AC} = F_{CE} = F_{EG} = F_{GH} =$
1200 lb *T*; $F_{BC} = F_{FG} = 0$; $F_{BD} = F_{DF} = 1000$ lb *C*;
$F_{BE} = F_{EF} = 500$ lb *C*; $F_{DE} = 600$ lb *T*.

6.12 $F_{AB} = F_{FH} = 1500$ lb C; $F_{AC} = F_{CE} = F_{EG} = F_{GH} = 1200$ lb T; $F_{BC} = F_{FG} = 0$; $F_{BD} = F_{DF} = 1200$ lb C; $F_{BE} = F_{EF} = 60.0$ lb C; $F_{DE} = 72.0$ lb T.

6.15 $F_{AB} = 7.50$ kips C; $F_{AC} = 4.50$ kips T; $F_{BC} = 7.50$ kips T; $F_{BD} = 9.00$ kips C; $F_{CD} = 0$; $F_{CE} = 9.00$ kips T.

6.16 $F_{AB} = 5.00$ kips C; $F_{AC} = 3.00$ kips T; $F_{BC} = 5.00$ kips T; $F_{BD} = 6.00$ kips C; $F_{CD} = F_{EF} = 2.50$ kips T; $F_{CE} = 4.50$ kips T; $F_{DE} = F_{FG} = 2.50$ kips C; $F_{DF} = 3.00$ kips C; $F_{EG} = 1.500$ kips T.

6.19 $F_{AB} = 9.90$ kN C; $F_{AC} = 7.83$ kN T; $F_{BC} = 0$; $F_{BD} = 7.07$ kN C; $F_{BE} = 2.00$ kN C; $F_{CE} = 7.83$ kN T; $F_{DE} = 1.000$ kN T; $F_{DF} = 5.03$ kN C; $F_{DG} = 0.559$ kN C; $F_{EG} = 5.59$ kN T.

6.20 $F_{FG} = 3.50$ kN T; $F_{FH} = 5.03$ kN C; $F_{GH} = 1.677$ kN T; $F_{GI} = F_{IK} = F_{KL} = 3.35$ kN T; $F_{HI} = F_{IJ} = F_{JK} = 0$; $F_{HJ} = F_{JL} = 4.42$ kN C.

6.21 $F_{AB} = 2240$ lb C; $F_{AC} = F_{CE} = 2000$ lb T; $F_{BC} = F_{EH} = 0$; $F_{BD} = 1789$ lb C; $F_{BE} = 447$ lb C; $F_{DE} = 600$ lb C; $F_{DF} = 2010$ lb C; $F_{DG} = 224$ lb T; $F_{EG} = 1789$ lb T.

6.22 $F_{FG} = 1400$ lb T; $F_{FI} = 2010$ lb C; $F_{GI} = 671$ lb C; $F_{GJ} = 2430$ lb T; $F_{IJ} = 361$ lb T; $F_{IK} = 2910$ lb C; $F_{JK} = 447$ lb C; $F_{JL} = 3040$ lb T; $F_{KL} = 3350$ lb C.

6.23 $F_{AB} = 9.39$ kN C; $F_{AC} = 8.40$ kN T; $F_{BC} = 2.26$ kN C; $F_{BD} = 7.60$ kN C; $F_{CD} = 0.128$ kN C; $F_{CE} = 7.07$ kN T; $F_{DE} = 2.14$ kN C; $F_{DF} = 6.10$ kN C; $F_{EF} = 2.23$ kN T.

6.24 $F_{AB} = F_{DF} = 2.29$ kN T; $F_{AC} = F_{EF} = 2.29$ kN C; $F_{BC} = F_{DE} = 0.600$ kN C; $F_{BD} = 2.21$ kN T; $F_{BE} = F_{EH} = 0$; $F_{CE} = 2.21$ kN C; $F_{CH} = F_{EJ} = 1.200$ kN C.

6.27 $F_{AB} = 31.0$ kips C; $F_{AC} = 28.3$ kips C; $F_{AD} = 15.09$ kips T; $F_{AE} = 9.50$ kips T; $F_{BD} = 21.5$ kips T; $F_{BF} = 28.0$ kips C; $F_{CE} = 41.0$ kips T; $F_{CG} = 42.0$ kips C; $F_{DE} = 22.0$ kips T; $F_{DF} = 33.5$ kips T; $F_{EG} = 0$.

6.28 $F_{AB} = 128.0$ kN T; $F_{AC} = 136.7$ kN C; $F_{BD} = F_{DF} = F_{FH} = 128.0$ kN T; $F_{CE} = F_{EG} = 136.7$ kN C; $F_{GH} = 192.7$ kN C.

6.29 Truss of Prob. 6.33*a* is the only simple truss.

6.30 Truss of Prob. 6.32*b* is the only simple truss.

6.31 (*a*) *BC*, *CD*, *IJ*, *IL*, *LM*, *MN*. (*b*) *BC*, *BE*, *DE*, *EF*, *FG*, *IJ*, *KN*, *MN*.

6.32 (*a*) *AI*, *BJ*, *CK*, *DI*, *EI*, *FK*, *GK*. (*b*) *FK*, *IO*.

6.35 $F_{AB} = F_{AD} = 244$ lb C; $F_{AC} = 1040$ lb T; $F_{BC} = F_{CD} = 500$ lb C; $F_{BD} = 280$ lb T.

6.36 $F_{AB} = F_{AD} = 861$ N C; $F_{AC} = 676$ N C; $F_{BC} = F_{CD} = 162.5$ N T; $F_{BD} = 244$ N T.

6.37 $F_{AB} = F_{AD} = 2810$ N T; $F_{AC} = 5510$ N C; $F_{BC} = F_{CD} = 1325$ N T; $F_{BD} = 1908$ N C.

6.38 $F_{AB} = F_{AC} = 1061$ lb C; $F_{AD} = 2500$ lb T; $F_{BC} = 2100$ lb T; $F_{BD} = F_{CD} = 1250$ lb C; $F_{BE} = F_{CE} = 1250$ lb C; $F_{DE} = 1500$ lb T.

6.39 $F_{AB} = 840$ N C; $F_{AC} = 110.6$ N C; $F_{AD} = 394$ N C; $F_{AE} = 0$; $F_{BC} = 160.0$ N T; $F_{BE} = 200$ N T; $F_{CD} = 225$ N T; $F_{CE} = 233$ N C; $F_{DE} = 120.0$ N T.

6.40 $F_{AB} = 0$; $F_{AC} = 995$ N T; $F_{AD} = 1181$ N C; $F_{AE} = F_{BC} = 0$; $F_{BE} = 600$ N T; $F_{CD} = 375$ N T; $F_{CE} = 700$ N C; $F_{DE} = 360$ N T.

6.43 $F_{CE} = 8000$ lb T; $F_{DE} = 2600$ lb T; $F_{DF} = 9000$ lb C

6.44 $F_{EG} = 7500$ lb T; $F_{FG} = 3900$ lb C; $F_{FH} = 6000$ lb C

6.45 $F_{BD} = 216$ kN T; $F_{DE} = 270$ kN T.

6.46 $F_{DG} = 459$ kN C; $F_{EG} = 216$ kN C.

6.49 $F_{CE} = 7.20$ kN T; $F_{DE} = 1.047$ kN C; $F_{DF} = 6.39$ kN C.

6.50 $F_{EG} = 3.46$ kN T; $F_{GH} = 3.78$ kN C; $F_{HJ} = 3.55$ kN C.

6.51 $F_{DF} = 10.48$ kips C; $F_{DG} = 3.35$ kips C; $F_{EG} = 13.02$ kips T.

6.52 $F_{OI} = 13.02$ kips T; $F_{HI} = 0.800$ kips T; $F_{HJ} = 13.97$ kips C.

6.53 $F_{CE} = 8.00$ kN T; $F_{DE} = 4.50$ kN C; $F_{DF} = 10.00$ kN C.

6.54 $F_{FH} = 10.00$ kN C; $F_{FI} = 4.92$ kN T; $F_{GI} = 6.00$ kN T.

6.55 $F_{AD} = 13.5$ kN C; $F_{CD} = 0$; $F_{CE} = 56.1$ kN T.

6.56 $F_{DG} = 75.0$ kN C; $F_{FG} = 56.1$ kN T; $F_{FH} = 69.7$ kN T.

6.57 $F_{AB} = 8.20$ kips T; $F_{AG} = 4.50$ kips T; $F_{FG} = 11.60$ kips C.

6.58 $F_{AE} = 17.46$ kips T; $F_{EF} = 11.60$ kips C; $F_{FJ} = 18.45$ kips C.

6.61 $F_{AF} = 1.500$ kN T; $F_{EJ} = 0.900$ kN T.

6.62 $F_{AF} = 0.900$ kN T; $F_{EJ} = 0.300$ kN T.

6.65 (*a*) *CJ*. (*b*) 1.026 kN T.

6.66 (*a*) *IO*. (*b*) 2.05 kN T.

6.67 $F_{BG} = 5.48$ kips T; $F_{DG} = 1.825$ kips T.

6.68 $F_{CF} = 3.65$ kips T; $F_{CH} = 7.30$ kips T.

6.69 (*a*) improperly constrained. (*b*) completely constrained, determinate. (*c*) completely constrained, indeterminate.

6.70 (*a*) completely constrained, determinate. (*b*) partially constrained. (*c*) improperly constrained.

6.71 (*a*) completely constrained, determinate. (*b*) completely constrained, indeterminate. (*c*) improperly constrained.

6.72 (*a*) partially constrained. (*b*) completely constrained, determinate. (*c*) completely constrained, indeterminate.

6.75 (*a*) 125 N ⦤ 36.9°. (*b*) 125 N ⦥ 36.9°.

6.76 $F_{BD} = 255$ N C; $\mathbf{C}_x = 120.0$ N $\rightarrow$; $\mathbf{C}_y = 625$ N $\uparrow$.

6.77 (*a*) 80.0 lb T. (*b*) 72.1 lb ⦥ 16.1°.

6.78 (*a*) 80.0 lb T. (*b*) 72.1 lb ⦤ 16.1°.

6.81 $\mathbf{A}_x = 18.00$ kN $\leftarrow$; $\mathbf{A}_y = 20.0$ kN $\downarrow$; $\mathbf{B} = 9.00$ kN $\rightarrow$; $\mathbf{C}_x = 9.00$ kN $\rightarrow$, $\mathbf{C}_y = 20.0$ kN $\uparrow$.

6.82 $\mathbf{A} = 20.0$ kN $\downarrow$; $\mathbf{B} = 18.00$ kN $\leftarrow$; $\mathbf{C}_x = 18.00$ kN $\rightarrow$, $\mathbf{C}_y = 20.0$ kN $\uparrow$.

6.83 (*a*) $\mathbf{A}_x = 450$ N $\leftarrow$, $\mathbf{A}_y = 525$ N $\uparrow$; $\mathbf{E}_x = 450$ N $\rightarrow$, $\mathbf{E}_y = 225$ N $\uparrow$; (*b*) $\mathbf{A}_x = 450$ N $\leftarrow$, $\mathbf{A}_y = 150.0$ N $\uparrow$; $\mathbf{E}_x = 450$ N $\rightarrow$, $\mathbf{E}_y = 600$ N $\uparrow$.

6.84 (*a*) $\mathbf{A}_x = 300$ N $\leftarrow$, $\mathbf{A}_y = 660$ N $\uparrow$; $\mathbf{E}_x = 300$ N $\rightarrow$, $\mathbf{E}_y = 90.0$ N $\uparrow$. (*b*) $\mathbf{A}_x = 300$ N $\leftarrow$, $\mathbf{A}_y = 150.0$ N $\uparrow$; $\mathbf{E}_x = 300$ N $\rightarrow$, $\mathbf{E}_y = 600$ N $\uparrow$.

6.87 (*a*) $\mathbf{A}_x = 80.0$ lb $\leftarrow$, $\mathbf{A}_y = 40.0$ lb $\uparrow$; $\mathbf{B}_x = 80.0$ lb $\rightarrow$, $\mathbf{B}_y = 60.0$ lb $\uparrow$. (*b*) $\mathbf{A}_x = 0$, $\mathbf{A}_y = 40.0$ lb $\uparrow$; $\mathbf{B}_x = 0$, $\mathbf{B}_y = 60.0$ lb $\uparrow$.

6.88 (*a*) and (*c*) $\mathbf{B}_x = 32.0$ lb $\rightarrow$, $\mathbf{B}_y = 10.00$ lb $\uparrow$; $\mathbf{F}_x = 32.0$ lb $\leftarrow$, $\mathbf{F}_y = 38.0$ lb $\uparrow$. (*b*) $\mathbf{B}_x = 32.0$ lb $\rightarrow$, $\mathbf{B}_y = 34.0$ lb $\uparrow$, $\mathbf{F}_x = 32.0$ lb $\leftarrow$, $\mathbf{F}_y = 14.00$ lb $\uparrow$.

6.89 (*a*) and (*c*) $\mathbf{B}_x = 24.0$ lb $\leftarrow$, $\mathbf{B}_y = 7.50$ lb $\downarrow$; $\mathbf{F}_x = 24.0$ lb $\rightarrow$, $\mathbf{F}_y = 7.50$ lb $\uparrow$. (*b*) $\mathbf{B}_x = 24.0$ lb $\leftarrow$, $\mathbf{B}_y = 10.50$ lb $\uparrow$; $\mathbf{F}_x = 24.0$ lb $\rightarrow$, $\mathbf{F}_y = 10.50$ lb $\downarrow$.

6.91 $\mathbf{B}_x = 700$ N $\leftarrow$, $\mathbf{B}_y = 200$ N $\downarrow$; $\mathbf{E}_x = 700$ N $\rightarrow$, $\mathbf{E}_y = 500$ N $\uparrow$.

6.92 $\mathbf{D}_x = 13.60$ kN $\rightarrow$, $\mathbf{D}_y = 7.50$ kN $\uparrow$; $\mathbf{E}_x = 13.60$ kN $\leftarrow$, $\mathbf{E}_y = 2.70$ kN $\downarrow$

6.93 $\mathbf{A}_x = 176.3$ lb $\leftarrow$, $\mathbf{A}_y = 60.0$ lb $\downarrow$; $\mathbf{G}_x = 56.3$ lb $\rightarrow$, $\mathbf{G}_y = 510$ lb $\uparrow$.

6.94 $\mathbf{A}_x = 56.3$ lb $\leftarrow$, $\mathbf{A}_y = 157.5$ lb $\downarrow$; $\mathbf{G}_x = 56.3$ lb $\rightarrow$, $\mathbf{G}_y = 383$ lb $\uparrow$.

6.95 (*a*) $\mathbf{A} = 982$ lb $\uparrow$; $\mathbf{B} = 935$ lb $\uparrow$; $\mathbf{C} = 733$ lb $\uparrow$. (*b*) $\Delta B = +291$ lb; $\Delta C = -72.7$ lb.

6.96 (*a*) = 572 lb. (*b*) $\mathbf{A} = 1070$ lb $\uparrow$; $\mathbf{B} = 709$ lb $\uparrow$; $\mathbf{C} = 870$ lb $\uparrow$.

6.99 $\mathbf{C}_x = 78.0$ lb $\rightarrow$, $\mathbf{C}_y = 28.0$ lb $\uparrow$; $\mathbf{F}_x = 78.0$ lb $\leftarrow$, $\mathbf{F}_y = 12.00$ lb $\uparrow$.

6.100 $\mathbf{C}_x = 21.7$ lb $\rightarrow$, $\mathbf{C}_y = 37.5$ lb $\downarrow$; $\mathbf{D}_x = 21.7$ lb $\leftarrow$, $\mathbf{D}_y = 62.5$ lb $\uparrow$.

6.101 $\mathbf{A}_x = 13.00$ kN $\leftarrow$, $\mathbf{A}_y = 4.00$ kN $\downarrow$; $\mathbf{B}_x = 36.0$ kN $\rightarrow$, $\mathbf{B}_y = 6.00$ kN $\uparrow$; $\mathbf{E}_x = 23.0$ kN $\leftarrow$, $\mathbf{E}_y = 2.00$ kN $\downarrow$.

6.102 $\mathbf{A}_x = 2025$ N $\leftarrow$, $\mathbf{A}_y = 1800$ N $\downarrow$; $\mathbf{B}_x = 4050$ N $\rightarrow$, $\mathbf{B}_y = 1200$ N $\uparrow$; $\mathbf{E}_x = 2025$ N $\leftarrow$, $\mathbf{E}_y = 600$ N $\uparrow$.

6.103 (*a*) $\mathbf{C}_x = 100.0$ lb ←, $\mathbf{C}_y = 100.0$ lb ↑; $\mathbf{D}_x = 100.0$ lb →, $\mathbf{D}_y = 20.0$ lb ↓. (*b*) $\mathbf{E}_x = 100.0$ lb ←, $\mathbf{E}_y = 180.0$ lb ↑.
6.104 (*a*) $\mathbf{C}_x = 100.0$ lb ←, $\mathbf{C}_y = 60.0$ lb ↑; $\mathbf{D}_x = 100.0$ lb →, $\mathbf{D}_y = 20.0$ lb ↑. (*b*) $\mathbf{E}_x = 100.0$ lb ←, $\mathbf{E}_y = 140.0$ lb ↑.
6.107 (*a*) $\mathbf{A}_x = 200$ kN →, $\mathbf{A}_y = 122$ kN ↑. (*b*) $\mathbf{B}_x = 200$ kN ←, $\mathbf{B}_y = 10.00$ kN ↓.
6.108 (*a*) $\mathbf{A}_x = 205$ kN →, $\mathbf{A}_y = 134.5$ kN ↑. (*b*) $\mathbf{B}_x = 205$ kN ←, $\mathbf{B}_y = 5.50$ kN ↑.
6.109 $\mathbf{B} = 98.5$ lb ∠ 24.0°; $\mathbf{C} = 90.6$ lb ∠ 6.34°.
6.110 (*a*) 301 lb ∠ 48.4°. (*b*) 375 lb *T*.
6.111 $F_{AG} = \sqrt{2}\,P/6$ *C*; $F_{BF} = 2\sqrt{2}\,P/3$ *C*; $F_{DI} = \sqrt{2}\,P/3$ *C*; $F_{EH} = \sqrt{2}\,P/6$ *T*.
6.113 $F_{AF} = P/4$ *C*; $F_{BG} = F_{DG} = P/\sqrt{2}$ *C*; $F_{EH} = P/4$ *T*.
6.115 $F_{AF} = M_0/4a$ *C*; $F_{BG} = F_{DG} = M_0/\sqrt{2}a$ *T*; $F_{EH} = 3M_0/4a$ *C*.
6.116 $F_{AF} = \sqrt{2}\,M_0/3a$ *C*; $F_{BG} = M_0/a$ *T*; $F_{DG} = M_0/a$ *C*; $F_{EH} = 2\sqrt{2}\,M_0/3a$ *T*.
6.117 $\mathbf{E} = P/5$ ↓; $\mathbf{F} = 8P/5$ ↑; $\mathbf{G} = 4P/5$ ↓; $\mathbf{H} = 2P/5$ ↑.
6.118 $\mathbf{A} = P/15$ ↑; $\mathbf{D} = 2P/15$ ↑; $\mathbf{E} = 8P/15$ ↑; $\mathbf{H} = 4P/15$ ↑.
6.119 (*a*) $\mathbf{A} = 2.06P$ ∠ 14.04°; $\mathbf{B} = 2.06P$ ∠ 14.04°; frame is rigid. (*b*) Frame is not rigid. (*c*) $\mathbf{A} = 1.25P$ ∠ 36.9°; $\mathbf{B} = 1.031P$ ∠ 14.04°; frame is rigid.
6.122 (*a*) $(F_{BD})_y = 96.0$ lb ↓ (*b*) $F_{BD} = 100.0$ lb ∠ 73.7°.
6.123 (*a*) $(F_{BD})_y = 240$ lb ↓ (*b*) $F_{BD} = 250$ lb ∠ 73.7°.
6.126 (*a*) 746 N ↓. (*b*) 565 N ∠ 61.3°.
6.127 (*a*) 302 N ↓. (*b*) 682 N ∠ 61.3°.
6.128 $T_{DE} = 81.0$ N; $\mathbf{B} = 216$ N ↓.
6.129 (*a*) 21.0 kN ←. (*b*) 52.5 kN ←.
6.130 (*a*) 1143 N · m ↓. (*b*) 457 N · m ↓.
6.131 832 lb · in. ↰.
6.132 360 lb · in. ↰.
6.133 195.0 kN · m ↓.
6.134 40.5 kN · m ↰.
6.137 208 N · m ↓.
6.138 18.43 N · m ↓.
6.139 $F_{AE} = 800$ N *T*; $F_{DG} = 100.0$ N *C*.
6.140 $\mathbf{P} = 120.0$ N ↓; $\mathbf{Q} = 110.0$ N ←.
6.142 $\mathbf{F} = 3290$ lb ∠ 15.12°; $\mathbf{D} = 4450$ lb ←.
6.143 $\mathbf{D} = 30.0$ kN ←; $\mathbf{F} = 37.5$ kN ∠ 36.9°.
6.144 $\mathbf{D} = 150.0$ kN ←; $\mathbf{F} = 96.4$ kN ∠ 13.50°.
6.145 (*a*) 475 lb. (*b*) 528 lb ∠ 63.3°.
6.146 44.8 kN.
6.148 8.45 kN.
6.149 25.0 lb ↓
6.150 10.00 lb ↓.
6.151 240 N.
6.154 (*a*) 14.11 kN ∠ 19.10°. (*b*) 19.79 kN ∠ 47.6°.
6.155 (*a*) 4.91 kips *C*. (*b*) 10.69 kips *C*.
6.156 (*a*) 2.86 kips *C*. (*b*) 9.43 kips *C*.
6.159 (*a*) $M_0 = (90.0\text{ N} \cdot \text{m})\mathbf{i}$. (*b*) $\mathbf{A} = 0$; $\mathbf{B} = 0$; $\mathbf{M}_B = -(72.0\text{ N} \cdot \text{m})\mathbf{i}$
6.160 (*a*) 27.0 mm. (*b*) 40.0 N · m ↓.
6.163 $\mathbf{E}_x = 100.0$ kN →, $\mathbf{E}_y = 154.9$ kN ↑; $\mathbf{F}_x = 26.5$ kN →, $\mathbf{F}_y = 118.1$ kN ↓; $\mathbf{H}_x = 126.5$ kN ←, $\mathbf{H}_y = 36.8$ kN ↓.
6.164 $F_{AB} = F_{AE} = 671$ lb *T*; $F_{AC} = F_{AD} = 1000$ lb *C*; $F_{BC} = F_{DE} = 600$ lb *C*; $F_{CD} = 200$ lb *T*.
6.166 $F_{FG} = 5.23$ kN *C*; $F_{EG} = 0.1476$ kN *C*; $F_{EH} = 5.08$ kN *T*.
6.167 $F_{KM} = 5.02$ kN *T*; $F_{LM} = 1.963$ kN *C*; $F_{LN} = 3.95$ kN *C*.
6.168 $\mathbf{A}_x = 25.0$ kips ←, $\mathbf{A}_y = 20.0$ kips ↑; $\mathbf{B}_x = 25.0$ kips ←, $\mathbf{B}_y = 10.00$ kips ↓; $\mathbf{C}_x = 50.0$ kips →, $\mathbf{C}_y = 10.00$ kips ↓.
6.170 $\mathbf{A}_x = 150.0$ N ←, $\mathbf{A}_y = 250$ N ↑; $\mathbf{E}_x = 150.0$ N →, $\mathbf{E}_y = 450$ N ↑.
6.171 $\mathbf{A} = 327$ lb →; $\mathbf{B} = 827$ lb ←; $\mathbf{D} = 621$ lb ↑; $\mathbf{E} = 246$ lb ↑.
6.172 (*a*) $\mathbf{P} = 109.8$ N →. (*b*) 126.8 N *T*, (*c*) 139.8 N ∠ 38.3°.
6.175 (*a*) 312 lb. (*b*) 135.0 lb · in. ↲.
6.C1 (*a*) $\theta = 30°$: $W = 472$ lb, $A_{AB} = 1.500$ in^2, $A_{AC} = A_{CE} = 1.299$ in^2, $A_{BC} = A_{BE} = 0.500$ in^2, $A_{BD} = 1.732$ in^2. (*b*) $\theta_{\text{opt}} = 56.8°$: $W = 312$ lb, $A_{AB} = 0.896$ in^2, $A_{AC} = A_{CE} = 0.491$ in^2, $A_{BC} = 0.500$ in^2, $A_{BE} = 0.299$ in^2, $A_{BD} = 0.655$ in^2.
6.C2 (*a*) For $x = 9.75$ m, $F_{BH} = 3.19$ kN *T*. (*b*) For $x = 3.75$ m, $F_{BH} = 1.313$ kN *C*. (*c*) For $x = 6$ m, $F_{GH} = 3.04$ kN *T*.
6.C3 $\theta = 30°$: $\mathbf{M} = 5860$ lb · ft ↰; $\mathbf{A} = 670$ lb ∠ 75.5°. (*a*) $M_{\max} = 8680$ lb · ft when $\theta = 65.9°$. (*b*) $A_{\max} = 1436$ lb when $\theta = 68.5°$.
6.C4 $\theta = 30°$: $\mathbf{M}_A = 1.669$ N · m ↰, $F = 11.79$ N. $\theta = 80°$: $\mathbf{M}_A = 3.21$ N · m ↰, $F = 11.98$ N.
6.C5 $d = 0.40$ *in.*: 634 lb *C*; $d = 0.55$ *in.*: 286 lb *C*; $d = 0.473$ *in.*: $F_{AB} = 500$ lb *C*.
6.C6 $\theta = 20°$: $M = 31.8$ N · m; $\theta = 75°$: $M = 12.75$ N · m; $\theta = 60.0°$: $M_{\min} = 12.00$ N · m.

CHAPTER 7

7.1 $\mathbf{F} = 0$; $\mathbf{V} = 80.0$ lb ↑; $\mathbf{M} = 480$ lb · in. ↰.
7.2 $\mathbf{F} = 0$; $\mathbf{V} = 40.0$ lb ↑; $\mathbf{M} = 240$ lb · in. ↰.
7.3 $\mathbf{F} = 4.80$ kN ←; $\mathbf{V} = 1.400$ kN ↓; $\mathbf{M} = 1.380$ kN · m ↲.
7.4 $\mathbf{F} = 3.00$ kN ←; $\mathbf{V} = 0$; $\mathbf{M} = 0.600$ kN · m ↲.
7.7 (On *AJ*) $\mathbf{F} = 103.9$ N ↖; $\mathbf{V} = 60.0$ N ↗; $\mathbf{M} = 18.71$ N · m ↲.
7.8 (On *BK*) $\mathbf{F} = 60.0$ N ↙; $\mathbf{V} = 103.9$ N ↘; $\mathbf{M} = 10.80$ N · m ↰.
7.9 (On *CJ*) $\mathbf{F} = 23.6$ lb ↘; $\mathbf{V} = 29.1$ lb ↙; $\mathbf{M} = 540$ lb · in. ↰.
7.10 (*a*) 30.0 lb at *C*. (*b*) 33.5 lb at *B* and *D*. (*c*) 960 lb · in. at *C*.
7.13 (On *AJ*) $\mathbf{F} = 194.6$ N ∠ 60°; $\mathbf{V} = 257$ N ∠ 30°; $\mathbf{M} = 24.7$ N · m ↲.
7.14 45.2 N · m for $\theta = 82.9°$.
7.15 (*a*) $\mathbf{F} = 500$ N ←; $\mathbf{V} = 500$ N ↑; $\mathbf{M} = 300$ N · m ↲. (*b*) $\mathbf{F} = 970$ N ↑; $\mathbf{V} = 171.0$ N ←; $\mathbf{M} = 446$ N · m ↲.
7.16 (*a*) $\mathbf{F} = 500$ N ←; $\mathbf{V} = 500$ N ↑; $\mathbf{M} = 300$ N · m ↲. (*b*) $\mathbf{F} = 933$ N ↑; $\mathbf{V} = 250$ N ←; $\mathbf{M} = 375$ N · m ↲.
7.17 (On *BJ*) $\mathbf{F} = 200$ N ↘; $\mathbf{V} = 120.0$ N ↗; $\mathbf{M} = 120.0$ N · m ↰.
7.18 (On *AK*) $\mathbf{F} = 520$ N ←; $\mathbf{V} = 120.0$ N ↓; $\mathbf{M} = 96.0$ N · m ↲.
7.19 150.0 lb · in. at *D*.
7.20 105.0 lb · in. at *E*.
7.23 (On *BJ*) $0.289Wr$ ↰.
7.24 (On *BJ*) $0.417Wr$ ↰.
7.27 $0.1009Wr$ for $\theta = 57.3°$.
7.28 $0.357Wr$ for $\theta = 49.3°$.
7.29 (*b*) $|V|_{\max} = 2P$; $|M|_{\max} = 3Pa$.
7.30 (*b*) $|V|_{\max} = 2P/3$; $|M|_{\max} = 2PL/9$.
7.31 (*b*) $wL/4$; $3wL^2/32$.
7.32 (*b*) $wL/2$; $3wL^2/8$.
7.35 (*b*) $|V|_{\max} = 35.0$ kN; $|M|_{\max} = 12.50$ kN · m.
7.36 (*b*) $|V|_{\max} = 50.5$ kN; $|M|_{\max} = 39.8$ kN · m.
7.39 (*b*) $|V|_{\max} = 64.0$ kN; $|M|_{\max} = 92.0$ kN · m.
7.40 (*b*) $|V|_{\max} = 60.0$ kN; $|M|_{\max} = 72.0$ kN · m.
7.41 (*b*) $|V|_{\max} = 18.00$ kips; $|M|_{\max} = 48.5$ kip · ft.
7.42 (*b*) $|V|_{\max} = 15.30$ kips; $|M|_{\max} = 46.8$ kip · ft.
7.43 (*b*) $|V|_{\max} = 1.800$ kN; $|M|_{\max} = 0.225$ kN · m.
7.44 (*b*) $|V|_{\max} = 2.00$ kN; $|M|_{\max} = 0.500$ kN · m.
7.45 (*a*) $M \le 0$ everywhere. (*b*) $|V|_{\max} = 4.50$ kips; $|M|_{\max} = 13.50$ kip · ft.
7.46 (*a*) $M \ge 0$ everywhere. (*b*) $|V|_{\max} = 4.50$ kips; $|M|_{\max} = 13.50$ kip · ft.

7.49 (*a*) +400 N; +160.0 N · m. (*b*) −200 N; +40.0 N · m.
7.52 $|V|_{\max} = 7.50$ kips; $|M|_{\max} = 7.20$ kip · ft.
7.53 $|V|_{\max} = 165$ lb; $|M|_{\max} = 1625$ lb · in.
7.54 $|V|_{\max} = 800$ N; $|M|_{\max} = 180.0$ N · m.
7.55 (*a*) 54.5°. (*b*) 675 N · m.
7.56 (*a*) 0.311 m. (*b*) 193.0 N · m.
7.57 (*a*) 1.236. (*b*) $0.1180wa^2$.
7.58 $a = 0.207L$
7.59 (*a*) 40.0 kips, (*b*) 40.0 kip · ft.
7.62 (*a*) $0.414wL$; $0.0858wL^2$. (*b*) $0.250wL$; $0.250wL^2$.
7.63 $|V|_{\max} = 2P$; $|M|_{\max} = 3Pa$
7.69 $|V|_{\max} = 7.20$ kN; $|M|_{\max} = 5.76$ kN · m.
7.70 $|V|_{\max} = 720$ N; $|M|_{\max} = 164.0$ N · m.
7.72 $|V|_{\max} = 60.0$ kN; $|M|_{\max} = 72.0$ kN · m.
7.77 (*b*) 9.00 kN · m, 1.700 m from *A*.
7.78 (*b*) 26.4 kN · m, 2.05 m from *A*.
7.79 (*b*) 45.0 kip · ft, 12.00 ft from *A*.
7.80 (*b*) 12.00 kip · ft, 6.00 ft from *A*.
7.83 (*b*) 40.5 kN · m, 1.800 m from *A*.
7.84 (*b*) 60.5 kN · m, 2.20 m from *A*.
7.85 (*a*) $V = (w_0/6L)(3x^2 - 6Lx + 2L^2)$;
$M = (w_0/6L)(x^3 - 3Lx^2 + 2L^2x)$.
(*b*) $0.0642w_0L^2$, at $x = 0.423L$.
7.86 (*a*) $V = (w_0/3L)(2x^2 - 3Lx + L^2)$;
$M = (w_0/18L)(4x^3 - 9Lx^2 + 6L^2x - L^3)$.
(*b*) $w_0L^2/72$, at $x = L/2$.
7.89 (*a*) $\mathbf{P} = 4.00$ kN ↓; $\mathbf{Q} = 6.00$ kN ↓. (*b*) $M_C = -900$ N · m.
7.90 (*a*) $\mathbf{P} = 2.50$ kN ↓; $\mathbf{Q} = 7.50$ kN ↓. (*b*) $M_C = -900$ N · m.
7.91 (*a*) $\mathbf{P} = 1.350$ kips ↓; $\mathbf{Q} = 0.450$ kips ↓.
(*b*) $V_{\max} = 2.70$ kips at *A*; $M_{\max} = 6.345$ kip · ft, 5.40 ft from *A*.
7.92 (*a*) $\mathbf{P} = 0.540$ kips ↓; $\mathbf{Q} = 1.860$ kips ↓.
(*b*) $|V|_{\max} = 3.14$ kips at *B*; $M_{\max} = 6.997$ kip · ft, 6.88 ft from *A*.
7.93 (*a*) 2.28 m. (*b*) $\mathbf{D}_x = 13.67$ kN →; $\mathbf{D}_y = 7.80$ kN ↑.
(*c*) 15.94 kN.
7.94 (*a*) 1.959 m. (*b*) 2.48 m.
7.95 (*a*) 838 lb ⦤ 17.4°. (*b*) 971 lb ⦣ 34.5°.
7.96 (*a*) 2670 lb ⦥ 2.10°. (*b*) 2810 lb ⦣ 18.6°.
7.97 (*a*) $d_B = 1.733$ m; $d_D = 4.20$ m. (*b*) 21.5 kN ⦣ 3.81°.
7.98 (*a*) 2.80 m. (*b*) $\mathbf{A} = 32.0$ kN ⦤ 38.7°; $\mathbf{E} = 25.0$ kN →.
7.101 (*a*) 48.0 lb. (*b*) 10.00 ft.
7.102 (*a*) 12.50 ft. (*b*) 5.00 ft.
7.103 196.2 N.
7.104 157.0 N.
7.107 (*a*) 138.1 m. (*b*) 602 N.
7.108 (*a*) 6.75 m. (*b*) $T_{AB} = 615$ N; $T_{BC} = 600$ N.
7.109 (*a*) 56,400 kips. (*b*) 4280 ft.
7.110 (*a*) 50,200 kips. (*b*) 3580 ft.
7.113 (a) $\sqrt{3L\Delta/8}$. (*b*) 12.25 ft.
7.114 3.75 ft.
7.115 (*a*) 58900 kips. (*b*) 29.2°.
7.116 (*a*) 16.00 ft to the left of *B*. (*b*) 2000 lb.
7.117 (*a*) 5880 N. (*b*) 0.873 m.
7.118 (*a*) 6860 N. (*b*) 31.0°.
7.125 $y = h[1 - \cos(\pi x/L)]$; $T_0 = w_0L^2/h\pi^2$;
$T_{\max} = (w_0L/\pi)\sqrt{(L^2/h^2\pi^2) + 1}$.
7.127 (*a*) 26.7 m. (*b*) 70.3 kg.
7.128 199.5 ft
7.129 (*a*) 164.8 m. (*b*) 4290 N.
7.130 330 ft; 625 lb.
7.133 (*a*) 5.89 m. (*b*) 10.89 N →.
7.134 10.05 ft.
7.135 (*a*) 30.2 m. (*b*) 56.6 kg.
7.136 (*a*) 56.3 ft. (*b*) 2.36 lb/ft.
7.139 31.8 N.
7.140 29.8 N.
7.141 (*a*) $a = 79.0$ ft; $b = 60.0$ ft. (*b*) 103.9 ft.
7.142 (*a*) $a = 65.8$ ft; $b = 50.0$ ft. (*b*) = 86.6 ft.
7.143 119.1 N →.
7.144 177.6 N →.
7.147 3.50 ft.
7.148 5.71 ft.
7.151 0.394 m and 10.97 m.
7.152 0.1408.
7.153 (*a*) 0.338. (*b*) 56.5°; $0.755wL$.
7.154 (*a*) 1500 N. (*b*) (On *ABJ*) $\mathbf{F} = 1324$ N ↑;
$\mathbf{V} = 706$ N ←; $\mathbf{M} = 229$ N · m ↰.
7.155 (On *BJ*) $\mathbf{F} = 250$ N ↘; $\mathbf{V} = 120.0$ N ↗; $\mathbf{M} = 120.0$ N · m ↰.
7.156 (*a*) (On *AC*) $\mathbf{F} = \mathbf{V} = 0$; $\mathbf{M} = 450$ lb · ft ↰.
(*b*) (On *AC*) $\mathbf{F} = 250$ lb ↙; $\mathbf{V} = 0$; $\mathbf{M} = 450$ lb · ft ↰.
7.157 (*a*) 90.0 lb. (*b*) 900 lb · in.
7.159 (*b*) 41.4 kN; 35.3 kN · m.
7.160 (*a*) 12.00 kip · ft, at *C*. (*b*) 6.25 kip · ft, 2.50 ft from *A*.
7.162 (*a*) 1229 lb. (*b*) 11.00 ft.
7.164 (*a*) 2770 N. (*b*) 75.14 m.
7.C1 (*a*) $M_D = +39.8$ kN · m. (*b*) $M_D = +14.00$ kip · ft.
(*c*) $M_D = +1800$ lb · in.
7.C3 $a = 1.923$ m; $M_{\max} = 37.0$ kN · m at 4.64 m from *A*.
7.C4 (*b*) $M_{\max} = 5.42$ kip · ft when $x = 8.5$ ft and 11.5 ft.
7.C8 $c/L = 0.300$: $h/L = 0.5225$; $s_{AB}/L = 1.532$;
$T_0/wL = 0.300$; $T_{\max}/wL = 0.823$.

CHAPTER 8

8.1 Equilibrium; $\mathbf{F} = 34.5$ lb ↘.
8.2 Block moves; $\mathbf{F} = 55.7$ lb ↖.
8.3 Equilibrium; $\mathbf{F} = 48.3$ N ↖.
8.4 Block moves; $\mathbf{F} = 103.5$ N ↖.
8.5 225 N ≤ P ≤ 479 N.
8.6 143.0 N ≤ P ≤ 483 N.
8.7 (*a*) 105.8 N. (*b*) 46.0°.
8.9 (*a*) 403 N. (*b*) 229 N.
8.11 (*a*) 353 N ←. (*b*) 196.2 N ←.
8.12 (*a*) 275 N ←. (*b*) 196.2 N ←.
8.15 (*a*) 36.0 lb →. (*b*) 30.0 lb. (*c*) 12.86 lb →.
8.16 (*a*) 36.0 lb →. (*b*) 40.0 in.
8.17 $M = Wr\mu_s(1 + \mu_s)/(1 + \mu_s^2)$.
8.18 (*a*) $0.300Wr$. (*b*) $0.349Wr$.
8.19 151.5 N · m.
8.20 1.473 kN.
8.21 0.208.
8.23 (*a*) 136.4°. (*b*) $0.928W$.
8.25 0.750.
8.26 0.860.
8.27 132.9 lb ↓.
8.28 (*a*) 112.5 N. (*b*) 8.81 mm.
8.29 $3.46 \le \dfrac{L}{a} \le 13.63$.
8.30 (*a*) Plate in equilibrium. (*b*) Plate moves downward.
8.31 10.00 lb < P < 36.7 lb.
8.34 135.0 lb.
8.36 168.4 N ≤ P ≤ 308 N.
8.37 9.38 N · m ≤ M ≤ 15.01 N · m.

8.38 $-46.8\text{ N} \le P \le 34.3\text{ N}$.
8.39 (*b*) 2.69 lb.
8.41 0.0949.
8.42 (*a*) System slides; $P = 62.8$ N.
(*b*) System rotates about *B*; $P = 73.2$ N.
8.43 35.8°.
8.44 20.5°.
8.45 1.225*W*.
8.46 (*a*) $\mathbf{P} = 56.6$ lb ←. (*b*) $\mathbf{B}_x = 82.6$ lb ←; $\mathbf{B}_y = 96.0$ lb ↓.
8.47 (*a*) $\mathbf{P} = 21.4$ lb →. (*b*) $\mathbf{B}_x = 122.2$ lb ←; $\mathbf{B}_y = 96.0$ lb ↓.
8.48 $\mathbf{P} = 2080$ N ↓.
8.49 $\mathbf{P} = 1966$ N ↓.
8.52 (*a*) 62.7 lb. (*b*) 62.7 lb.
8.53 9.86 kN ←.
8.54 913 N ←.
8.55 (*a*) 28.1°. (*b*) 728 N ∠ 14.04°.
8.56 29.9 lb.
8.57 67.4 N.
8.60 (*b*) 283 N ←.
8.61 0.442.
8.62 (*a*) 90.0 lb. (*b*) Base moves.
8.63 (*a*) 89.4 lb. (*b*) Base does not move.
8.64 0.1103.
8.65 0.1013.
8.69 1068 N · m.
8.70 4.18 N · m.
8.72 169.7 lb · in.
8.73 32.7 lb · in.
8.75 0.0980.
8.76 450 N.
8.77 412 N.
8.78 344 N.
8.79 376 N.
8.80 0.226.
8.82 $T_{AB} = 77.5$ lb; $T_{CD} = 72.5$ lb; $T_{EF} = 67.8$ lb.
8.85 22.0 lb ←.
8.86 1.948 lb ↓.
8.87 18.01 lb ←.
8.88 (*a*) 4.80 kN. (*b*) 1.375°.
8.90 3.75 lb.
8.91 0.1670.
8.96 154.4 N.
8.97 0.0600 in.
8.98 10.87 lb.
8.99 (*a*) 1.288 kN. (*b*) 1.058 kN.
8.100 300 mm.
8.101 (*a*) 0.329. (*b*) 2.67 turns.
8.102 (*a*) 22.8 kg. (*b*) 291 N.
8.103 (*a*) 109.7 kg. (*b*) 828 N.
8.104 $73.0\text{ lb} \le P \le 1233\text{ lb}$.
8.107 35.1 N · m
8.108 (*a*) 27.0 N · m (*b*) 675 N.
8.109 (*a*) 39.0 N · m. (*b*) 844 N.
8.110 421 lb · in.
8.111 301 lb · in.
8.112 44.9 N · m ↰.
8.115 4.49 in.
8.116 (*a*) 11.66 kg. (*b*) 38.6 kg. (*c*) 34.4 kg.
8.117 (*a*) 9.46 kg. (*b*) 167.2 kg. (*c*) 121.0 kg.
8.120 (*a*) 10.39 lb. (*b*) 58.5 lb.
8.121 (*a*) and (*b*) 28.9 lb.
8.122 5.97 N.
8.123 9.56 N.
8.124 (*a*) 30.3 lb · in ↰. (*b*) 3.78 lb ↓.
8.125 (*a*) 17.23 lb · in ↲. (*b*) 2.15 lb ↑.
8.126 0.350.
8.131 (*a*) 51.0 N · m. (*b*) 875 N.
8.132 (*a*) 170.5 N. (*b*) 14.04°.
8.133 53.5°.
8.135 $6.35 \le L/a \le 10.81$.
8.136 0.0533.
8.138 0.225.
8.139 (*a*) 620 N ←. (*b*) $\mathbf{B}_x = 1390$ N ←; $\mathbf{B}_y = 1050$ N ↓.
8.140 (*a*) and (*b*) 50.4 lb.
8.142 (*a*) 0.238. (*b*) 218 N ↓.
8.C1 *x = 500 mm*: 63.3 N; $P_{\max} = 67.8$ N at $x = 355$ mm.
8.C2 $W_B = 10$ *lb*: $\theta = 46.4°$; $W_B = 70$ *lb*: $\theta = 21.3°$.
8.C3 $\mu_A = 0.25$: $M = 0.0603$ N · m.
8.C4 $\theta = 30°$: $1.336\text{ N} \cdot \text{m} \le M_A \le 2.23\text{ N} \cdot \text{m}$.
8.C5 $\theta = 60°$: $\mathbf{P} = 16.40$ lb ↓; $R = 5.14$ lb.
8.C6 $\theta = 20°$: 10.39 N · m.
8.C7 $\theta = 20°$: 30.3 lb; 13.25 lb.
8.C8 (*a*) $x_0 = 0.600L$; $x_m = 0.604L$; $\theta_1 = 5.06°$. (*b*) $\theta_2 = 55.4°$.

CHAPTER 9

9.1 $b^3h/12$.
9.2 $3a^4/2$.
9.3 $2a^3b/15$.
9.4 $ha^3/5$.
9.6 $a^4/8$.
9.7 $2ab^3/7$.
9.9 $ab^3/15$.
9.10 $0.1056ab^3$.
9.11 $ab^3/15$.
9.12 $2a^3b/21$.
9.15 $ab^3/10$; $b/\sqrt{5}$.
9.16 $3ab^3/35$; $b\sqrt{9/35}$.
9.17 $a^3b/6$; $a/\sqrt{3}$.
9.18 $3a^3b/35$; $a\sqrt{9/35}$.
9.21 $20a^4$; $1.826a$.
9.22 $43a^4/48$; $0.773a$.
9.23 $(\pi/2)(R_2^4 - R_1^4)$; $(\pi/4)(R_2^4 - R_1^4)$.
9.24 (*b*) for $t/R_m = 1$, −10.56%; for $t/R_m = \frac{1}{2}$, −2,99%, for $t/R_m = \frac{1}{10}$, −0.1250%.
9.25 $64a^4/15$; $1.265a$.
9.28 $bh(12h^2 + b^2)/48$; $\sqrt{(12h^2 + b^2)/24}$.
9.31 390×10^3 mm^4; 21.9 mm.
9.32 46.0 in^4; 1.599 in.
9.33 64.3×10^3 mm^4; 8.87 mm.
9.34 46.5 in^4; 1.607 in.
9.37 $I = 9.50 \times 10^6$ mm^4; $d_2 = 60.0$ mm.
9.38 $A = 6600$ mm^2; $\bar{I} = 3.72 \times 10^6$ mm^4.
9.39 $\bar{I}_x = 150.0$ in^4; $\bar{I}_y = 300$ in^4.
9.41 $\bar{I}_x = 1.874 \times 10^6$ mm^4; $\bar{I}_y = 5.82 \times 10^6$ mm^4.
9.42 $\bar{I}_x = 48.9 \times 10^3$ mm^4; $\bar{I}_y = 8.35 \times 10^3$ mm^4.
9.43 $\bar{I}_x = 191.3$ in^4; $\bar{I}_y = 75.2$ in^4.
9.44 $\bar{I}_x = 18.13$ in^4; $\bar{I}_y = 4.51$ in^4.
9.45 (*a*) 80.9×10^6 mm^4. (*b*) 57.4×10^6 mm^4.
9.46 (*a*) 12.16×10^6 mm^4. (*b*) 9.73×10^6 mm^4.
9.49 $\bar{I}_x = 260 \times 10^6$ mm^4; $\bar{k}_x = 144.6$ mm; $\bar{I}_y = 17.53 \times 10^6$ mm^4; $\bar{k}_y = 37.6$ mm.
9.50 $\bar{I}_x = 254$ in^4; $\bar{k}_x = 4.00$ in.; $\bar{I}_y = 102.1$ in^4; $\bar{k}_y = 2.54$ in.

9.51 $\bar{I}_x = 255 \times 10^6$ mm^4; $\bar{k}_x = 134.1$ mm; $\bar{I}_y = 100.0 \times 10^6$ mm^4; $\bar{k}_y = 83.9$ mm.
9.52 1.077 in.
9.53 $\bar{I}_x = 3.55 \times 10^6$ mm^4; $\bar{I}_y = 49.8 \times 10^6$ mm^4.
9.55 $\bar{I}_x = 745 \times 10^6$ mm^4; $\bar{I}_y = 91.3 \times 10^6$ mm^4.
9.57 $3\pi r/16$.
9.58 $3\pi b/16$.
9.59 $15h/14$.
9.60 $4h/7$.
9.63 $5a/8$.
9.64 80.0 mm.
9.67 $a^4/2$.
9.68 $a^2b^2/12$.
9.69 $-b^2h^2/8$.
9.71 -1.760×10^6 mm^4.
9.72 -21.6×10^6 mm^4.
9.74 -0.380 in^4.
9.75 471×10^3 mm^4.
9.76 -9010 in^4.
9.78 1.165×10^6 mm^4.
9.79 (*a*) $\bar{I}_{x'} = 0.482a^4$; $\bar{I}_{y'} = 1.482a^4$; $\bar{I}_{x'y'} = -0.589a^4$.
(*b*) $\bar{I}_{x'} = 1.120a^4$; $\bar{I}_{y'} = 0.843a^4$; $\bar{I}_{x'y'} = 0.760a^4$.
9.80 $\bar{I}_{x'} = 103.5 \times 10^6$ mm^4; $\bar{I}_{y'} = 97.9 \times 10^6$ mm^4; $\bar{I}_{x'y'} = -38.3 \times 10^6$ mm^4.
9.81 $\bar{I}_{x'} = 1033$ in^4; $\bar{I}_{y'} = 2020$ in^4; $\bar{I}_{x'y'} = -873$ in^4.
9.83 $\bar{I}_{x'} = 0.236$ in^4; $\bar{I}_{y'} = 1.244$ in^4; $\bar{I}_{x'y'} = 0.1132$ in^4.
9.85 20.2°; $1.754a^4$, $0.209a^4$.
9.86 −17.11°; 139.1×10^6 mm^4, 62.3×10^6 mm^4.
9.87 29.7°; 2530 in^4, 524 in^4.
9.89 −23.7° and 66.3°; 1.257 in^4, 0.224 in^4.
9.91 (*a*) $\bar{I}_{x'} = 0.482a^4$; $\bar{I}_{y'} = 1.482a^4$; $\bar{I}_{x'y'} = -0.589a^4$.
(*b*) $\bar{I}_{x'} = 1.120a^4$; $\bar{I}_{y'} = 0.843a^4$; $\bar{I}_{x'y'} = 0.760a^4$.
9.92 $\bar{I}_{x'} = 103.5 \times 10^6$ mm^4; $\bar{I}_{y'} = 97.9 \times 10^6$ mm^4; $\bar{I}_{x'y'} = -38.3 \times 10^6$ mm^4.
9.93 $\bar{I}_{x'} = 1033$ in^4; $\bar{I}_{y'} = 2020$ in^4; $\bar{I}_{x'y'} = -873$ in^4.
9.95 $\bar{I}_{x'} = 0.236$ in^4; $\bar{I}_{y'} = 1.244$ in^4; $\bar{I}_{x'y'} = 0.1132$ in^4.
9.97 20.2°; $1.754a^4$, $0.209a^4$.
9.98 −17.11°; 139.1×10^6 mm^4, 62.3×10^6 mm^4.
9.99 −33.4°; 22.1×10^3 in^4, 2490 in^4.
9.100 29.7°; 2530 in^4, 524 in^4.
9.103 (*a*) −1.146 in^4. (*b*) 29.1° clockwise. (*c*) 3.39 in^4.
9.104 23.8° clockwise; 0.524×10^6 mm^4, 0.0917×10^6 mm^4.
9.105 19.54° counterclockwise; 4.34×10^6 mm^4, 0.647×10^6 mm^4.
9.106 (*a*) 25.3°. (*b*) 1459 in^4, 40.5 in^4.
9.107 (*a*) 88.0×10^6 mm^4. (*b*) 96.3×10^6 mm^4, 39.7×10^6 mm^4.
9.111 (*a*) $m(r_1^2 + r_2^2)/4$. (*b*) $m(r_1^2 + r_2^2)/2$.
9.112 (*a*) $0.0699ma^2$. (*b*) $0.320ma^2$.
9.113 (*a*) $25mr_2^2/64$. (*b*) $0.1522mr_2^2$.
9.114 (*a*) $mb^2/7$. (*b*) $m(7a^2 + 10b^2)/70$.
9.115 (*a*) $ma^2/3$. (*b*) $3ma^2/2$.
9.116 (*a*) $7ma^2/6$. (*b*) $ma^2/2$.
9.119 $1.329mh^2$.
9.120 $m(3a^2 + L^2)/12$.
9.121 (*a*) $0.241mh^2$. (*b*) $m(3a^2 + 0.1204h^2)$.
9.122 $m(b^2 + h^2)/10$.
9.124 $m(a^2 + b^2)/5$.
9.125 $I_x = I_y = ma^2/4$; $I_z = ma^2/2$.
9.127 837×10^{-9} kg · m^2; 6.92 mm.
9.128 1.160×10^{-6} lb · ft · s^2; 0.341 in.
9.129 $m(3a^2 + 2h^2)/6$.
9.131 (*a*) 27.5 mm to the right of A. (*b*) 32.0 mm.
9.133 (*a*) 2.30 in. (*b*) 20.6×10^{-3} lb · ft · s^2; 2.27 in.
9.134 (*a*) $\pi\rho l^2\left[6a^2t\left(\frac{5a^2}{3l^2} + \frac{2a}{l} + 1\right) + \frac{d^2l}{4}\right]$. (*b*) 0.1851.
9.135 $I_x = 26 \times 10^{-3}$ kg · m^2; $I_y = 38.2 \times 10^{-3}$ kg · m^2; $I_z = 17.55 \times 10^{-3}$ kg · m^2.
9.136 $I_x = 175.5 \times 10^{-3}$ kg · m^2; $I_y = 309 \times 10^{-3}$ kg · m^2; $I_z = 154.4 \times 10^{-3}$ kg · m^2.
9.137 $I_x = 745 \times 10^{-6}$ lb · ft · s^2; $I_y = 896 \times 10^{-6}$ lb · ft · s^2; $I_z = 304 \times 10^{-6}$ lb · ft · s^2.
9.138 $I_x = 344 \times 10^{-6}$ lb · ft · s^2; $I_y = 132.1 \times 10^{-6}$ lb · ft · s^2; $I_z = 453 \times 10^{-6}$ lb · ft · s^2.
9.141 (*a*) 13.99×10^{-3} kg · m^2. (*b*) 20.6×10^{-3} kg · m^2. (*c*) 14.30×10^{-3} kg · m^2.
9.142 0.1785 lb · ft · s^2.
9.144 $I_x = 38.1 \times 10^{-3}$ kg · m^2; $k_x = 110.7$ mm.
9.145 (*a*) 26.4×10^{-3} kg · m^2. (*b*) 31.2×10^{-3} kg · m^2. (*c*) 8.58×10^{-3} kg · m^2.
9.147 $I_x = 0.0392$ lb · ft · s^2; $I_y = 0.0363$ lb · ft · s^2; $I_z = 0.0304$ lb · ft · s^2.
9.148 $I_x = 0.323$ kg · m^2; $I_y = I_z = 0.419$ kg · m^2.
9.149 $I_{xy} = 2.50 \times 10^{-3}$ kg · m^2; $I_{yz} = 4.06 \times 10^{-3}$ kg · m^2; $I_{zx} = 8.81 \times 10^{-3}$ kg · m^2.
9.150 $I_{xy} = 2.44 \times 10^{-3}$ kg · m^2; $I_{yz} = 1.415 \times 10^{-3}$ kg · m^2; $I_{zx} = 4.59 \times 10^{-3}$ kg · m^2.
9.151 $I_{xy} = -538 \times 10^{-6}$ lb · ft · s^2; $I_{yz} = -171.4 \times 10^{-6}$ lb · ft · s^2; $I_{zx} = 1120 \times 10^{-6}$ lb · ft · s^2.
9.152 $I_{xy} = -1.726 \times 10^{-3}$ lb · ft · s^2; $I_{yz} = 0.507 \times 10^{-3}$ lb · ft · s^2; $I_{zx} = -2.12 \times 10^{-3}$ lb · ft · s^2.
9.155 $I_{xy} = -8.04 \times 10^{-3}$ kg · m^2; $I_{yz} = 12.90 \times 10^{-3}$ kg · m^2; $I_{zx} = 94.0 \times 10^{-3}$ kg · m^2.
9.156 $I_{xy} = 0$; $I_{yz} = 48.3 \times 10^{-6}$ kg · m^2; $I_{zx} = -4.43 \times 10^{-3}$ kg · m^2.
9.157 $I_{xy} = wa^3(1 - 5\pi)/g$; $I_{yz} = -11\pi wa^3/g$; $I_{zx} = 4wa^3(1 + 2\pi)g$.
9.158 $I_{xy} = -11wa^3/g$; $I_{yz} = wa^3(\pi + 6)/2g$; $I_{zx} = -wa^3/4g$.
9.159 $I_{xy} = 47.9 \times 10^{-6}$ kg · m^2; $I_{yz} = 102.1 \times 10^{-6}$ kg · m^2; $I_{zx} = 64.1 \times 10^{-6}$ kg · m^2.
9.160 $I_{xy} = -m'R_1^3/2$; $I_{yz} = m'R_1^3/2$; $I_{zx} = -m'R_2^3/2$.
9.162 (*a*) $mac/20$. (*b*) $I_{xy} = mab/20$; $I_{yz} = mbc/20$.
9.165 18.17×10^{-3} kg · m^2.
9.166 11.81×10^{-3} kg · m^2.
9.167 $5Wa^2/18g$.
9.168 $4.41\gamma ta^4/g$.
9.169 281×10^{-3} kg · m^2.
9.170 0.354 kg · m^2.
9.173 (*a*) $b/a = 2$; $c/a = 2$. (*b*) $b/a = 1$; $c/a = 0.5$.
9.174 (*a*) 2. (*b*) $\sqrt{2/3}$.
9.175 (*a*) $1/\sqrt{3}$. (*b*) $\sqrt{7/12}$.
9.179 (*a*) $K_1 = 0.363ma^2$; $K_2 = 1.583ma^2$; $K_3 = 1.720ma^2$.
(*b*) $(\theta_x)_1 = (\theta_z)_1 = 49.7°$, $(\theta_y)_1 = 113.7°$;
$(\theta_x)_2 = 45.0°$, $(\theta_y)_2 = 90.0°$, $(\theta_z)_2 = 135.0°$;
$(\theta_x)_3 = (\theta_z)_3 = 73.5°$, $(\theta_y)_3 = 23.7°$.
9.180 (*a*) $K_1 = 14.30 \times 10^{-3}$ kg · m^2;
$K_2 = 13.96 \times 10^{-3}$ kg · m^2; $K_3 = 20.6 \times 10^{-3}$ kg · m^2.
(*b*) $(\theta_x)_1 = (\theta_y)_1 = 90.0°$, $(\theta_z)_1 = 0$;
$(\theta_x)_2 = 3.42°$, $(\theta_y)_2 = 86.6°$, $(\theta_z)_2 = 90.0°$.
$(\theta_x)_3 = 93.4°$, $(\theta_y)_3 = 3.43°$, $(\theta_z)_3 = 90.0°$.
9.182 (*a*) $K_1 = 0.1639Wa^2/g$; $K_2 = 1.054Wa^2/g$; $K_3 = 1.115Wa^2/g$.
(*b*) $(\theta_x)_1 = 36.7°$, $(\theta_y)_1 = 71.6°$, $(\theta_z)_1 = 59.5°$;
$(\theta_x)_2 = 74.9°$, $(\theta_y)_2 = 54.5°$, $(\theta_z)_2 = 140.5°$;
$(\theta_x)_3 = 57.5°$, $(\theta_y)_3 = 138.8°$, $(\theta_z)_3 = 112.4°$.

9.183 (*a*) $K_1 = 2.26\gamma ta^4/g$; $K_2 = 17.27\gamma ta^4/g$; $K_3 = 19.08\gamma ta^4/g$.
(*b*) $(\theta_x)_1 = 85.0°$, $(\theta_y)_1 = 36.8°$, $(\theta_z)_1 = 53.7°$;
$(\theta_x)_2 = 81.7°$, $(\theta_y)_2 = 54.7°$, $(\theta_z)_2 = 143.4°$;
$(\theta_x)_3 = 9.70°$, $(\theta_y)_3 = 99.0°$, $(\theta_z)_3 = 86.3°$.
9.185 $I_x = ab^3/28$; $I_y = a^3b/20$.
9.187 $4a^3b/15$; $a/\sqrt{5}$.
9.188 $I_x = 4a^4$; $I_y = 16a^4/3$.
9.189 (*a*) 3.13×10^6 mm^4. (*b*) 2.41×10^6 mm^4.
9.190 $I_x = 634 \times 10^6$ mm^4; $I_y = 38.0 \times 10^6$ mm^4.
9.191 $I_{xy} = -2.81$ in^4.
9.193 (*a*) $7ma^2/18$. (*b*) $0.819ma^2$.
9.195 $I_x = 0.877$ kg · m^2; $I_y = 1.982$ kg · m^2; $I_z = 1.652$ kg · m^2.
9.C1 $\theta = 20°$: $I_{x'} = 14.20$ in^4, $I_{y'} = 3.15$ in^4, $I_{x'y'} = -3.93$ in^4.
9.C3 (*a*) $\bar{I}_{x'} = 371 \times 10^3$ mm^4, $\bar{I}_{y'} = 64.3 \times 10^3$ mm^4;
$\bar{k}_{x'} = 21.3$ mm, $\bar{k}_{y'} = 8.87$ mm. (*b*) $\bar{I}_{x'} = 40.4$ in^4,
$\bar{I}_{y'} = 46.5$ in^4; $\bar{k}_{x'} = 1.499$ in., $\bar{k}_{y'} = 1.607$ in.
(*c*) $\bar{k}_x = 2.53$ in., $\bar{k}_y = 1.583$ in. (*d*) $\bar{k}_x = 1.904$ in.,
$\bar{k}_y = 0.950$ in.
9.C5 (*a*) 5.99×10^{-3} kg · m^2. (*b*) 77.4×10^{-3} kg · m^2.
9.C6 (*a*) 74.0×10^{-6} lb · ft · s^2. (*b*) 645×10^{-6} lb · ft · s^2.
(*c*) 208×10^{-6} lb · ft · s^2.

CHAPTER 10

10.1 82.5 N ↓.
10.2 120 lb →.
10.3 49.5 N · m ↓.
10.4 1200 lb · in. ↰.
10.7 (*a*) 60.0 N *C*, 8.00 mm ↓. (*b*) 300 N *C*, 40.0 mm ↓.
10.8 (*a*) 120.0 N *C*, 16.00 mm ↓. (*b*) 300 N *C*, 40.0 mm ↓.
10.9 $Q = 2P \sin\theta/\cos(\theta/2)$.
10.10 $Q = 2P \cos\theta/\cos(\theta/2)$.
10.11 $Q = (3P/2)\tan\theta$
10.12 $Q = P[(l/a)\cos^3\theta - 1]$.
10.15 $M = \frac{1}{2}Wl \tan\alpha \sin\theta$.
10.16 $M = Pl/2 \tan\theta$.
10.17 $M = 7Pa \cos\theta$
10.18 (*a*) $M = Pl \sin 2\theta$. (*b*) $M = 3Pl \cos\theta$. (*c*) $M = Pl \sin\theta$.
10.21 85.2 lb · ft ↓.
10.22 22.8 lb ↙ 70.0°.
10.24 36.4°.
10.25 38.7°.
10.26 68.0°.
10.28 19.81° and 51.9°.
10.30 25.0°.
10.31 39.7° and 69.0°.
10.32 52.2°.
10.33 40.2°.
10.35 22.6°.
10.36 51.1°.
10.37 52.4°.
10.38 19.40°.
10.39 59.0°.
10.40 78.7°, 324°, 379°.
10.43 12.03 kN ↘.
10.44 20.4°.
10.45 2370 lb ↖.
10.46 2550 lb ↖.
10.47 $\eta = 1/(1 + \mu \cot\alpha)$
10.49 37.6 N, 31.6 N.
10.51 300 N · m, 81.8 N · m.
10.52 $\eta = \tan\theta/\tan(\theta + \phi_s)$.
10.53 7.75 kN ↑.
10.54 $H = 1.361$ kN ↑; $M_H = 550$ N · m ↰.
10.57 0.833 in. ↓.
10.58 0.625 in. →.
10.66 19.40°.
10.67 Equilibrium is neutral.
10.69 $\theta = 0$ and $\theta = 180.0°$, unstable;
$\theta = 75.5°$ and $\theta = 284°$, stable.
10.70 $\theta = 90.0°$ and $\theta = 270°$ unstable;
$\theta = 22.0°$ and $\theta = 158.0°$, stable.
10.71 $\theta = -45.0°$, unstable; $\theta = 135.0°$, stable.
10.72 $\theta = -63.4°$, unstable; $\theta = 116.6°$, stable.
10.73 59.0°, stable.
10.74 78.7°, stable; 324°, unstable; 379°, stable.
10.78 9.39° and 90.0°, stable; 34.2°, unstable.
10.79 357 mm.
10.80 252 mm.
10.81 17.11°, stable; 72.9°, unstable.
10.83 49.1°.
10.85 54.8°.
10.86 37.4°.
10.88 16.88 m.
10.90 $k > 6.94$ lb/in.
10.91 15.00 in.
10.92 $P < 2kL/9$.
10.93 $P < kL/18$.
10.94 $P < k(l - a)^2/2l$.
10.96 $P < 160.0$ N.
10.98 $P < 764$ N.
10.100 (*a*) $P < 10.00$ lb. (*b*) $P < 20.0$ lb.
10.101 60.0 lb ↓.
10.102 600 lb · in. ↓.
10.104 (*a*) 20.0 N. (*b*) 105.0 N.
10.106 39.2°.
10.107 60.4°.
10.108 7.13 in.
10.110 (*a*) 0, unstable. (*b*) 137.8°, stable.
10.112 (*a*) 22.0°. (*b*) 30.6°.
10.C1 $\theta = 60°$: 2.42 in.; $\theta = 120°$: 1.732 in.;
$(M/P)_{\max} = 2.52$ in. at $\theta = 73.7°$.
10.C2 $\theta = 60°$: 171.1 N *C*. For $32.5° \le \theta \le 134.3°$, $|F| \le 400$ N.
10.C3 $\theta = 60°$: 296 N *T*. For $\theta \le 125.7°$, $|F| \le 400$ N.
10.C4 (*b*) $\theta = 60°$, *datum at C*: $V = -294$ in · lb.
(*c*) 34.2°, stable; 90°, unstable; 145.8°, stable
10.C5 (*b*) $\theta = 50°$, *datum at E*: $V = 100.5$ J. $dV/d\theta = 22.9$ J.
(*c*) $\theta = 0$, unstable; 30.4°.
10.C6 (*b*) $\theta = 60°$, *datum at B*: 30.0 J.
(*c*) $\theta = 0$, unstable; 41.4°, stable.
10.C7 (*b*) $\theta = 60°$, *datum at* $\theta = 0$: −37.0 J. (*c*) 52.2°, stable.

CHAPTER 11

11.1 −66.0 m, 149.0 m/s, 228 m/s^2.
11.2 3.00 m, −7.00 m/s.
11.3 3.00 s, −59.5 ft, 25.0 ft/s^2.
11.4 248 in., 72.0 in./s, −383 in./s^2.
11.5 0.667 s, 0.259 m, −8.56 m/s.
11.6 (*a*) 1.000 s and 4.00 s. (*b*) 1.500 m, 24.5 m.
11.9 (*a*) 4.00 s. (*b*) −56.0 m/s, 260 m.

11.10 $x = t^4/108 + 10t + 24$, $v = t^3/27 + 10$.
11.11 −33.0 in./s, 2.00 s, 87.7 in.
11.12 (*a*) 3.00 ft/s^4. (*b*) $v = (t^3 - 32)$ ft/s, $x = (t^4/4 - 32t + 64)$ ft.
11.15 (*a*) 5.89 ft/s. (*b*) 1.772 ft.
11.16 −36.8 ft^2, 1.832 s^{-2}.
11.17 (*a*) 0.0900 s^{-2}. (*b*) ±16.97 mm/s.
11.18 (*a*) 48.0 m^3/s^2. (*b*) 21.6 m. (*c*) 4.90 m/s.
11.21 (*a*) 22.5 m. (*b*) 38.4 m/s.
11.22 (*a*) 29.3 m/s. (*b*) 0.947 s.
11.23 (*a*) 50.0 in. (*b*) ∞. (*c*) 0.866 s.
11.24 3.33 ft/s.
11.25 (*a*) 0.1457 s/m. (*b*) 145.2 m. (*c*) 6.86 m/s.
11.26 (*a*) 3.33 m. (*b*) 2.22 s. (*c*) 1.667 s.
11.27 (*a*) 7.15 mi. (*b*) -2.75×10^{-6} ft/s^2. (*c*) 49.9 min.
11.28 (*a*) −0.0525 m/s^2. (*b*) 6.17 s.
11.31 (*a*) 2.36 v_0T, $\pi v_0/T$. (*b*) 0.363 v_0.
11.33 (*a*) 1.500 m/s^2. (*b*) 10.00 s.
11.34 (*a*) 25.0 m/s. (*b*) 19.00 m/s. (*c*) 36.8 m.
11.35 (*a*) 2.71 s. (*b*) 50.4 mi/h.
11.36 (*a*) 252 ft/s. (*b*) 1076 ft.
11.39 (*a*) 0.500 km. (*b*) 42.9 km/h.
11.40 (*a*) −2.10 m/s^2, 2.06 m/s^2. (*b*) 2.59 s before *A* reaches the exchange zone.
11.41 (*a*) 15.05 s, 734 ft. (*b*) 42.5 mi/h, 23.7 mi/h.
11.42 (*a*) 5.50 ft/s^2. (*b*) 9.25 ft/s^2.
11.43 (*a*) 3.00 s. (*b*) 4.00 ft/s^2.
11.44 (*a*) −0.250 m/s^2, 0.300 m/s^2. (*b*) 20.8 s. (*c*) 85.5 km/h.
11.46 (*a*) 17.36 ft/s^2 ↙, 3.47 ft/s^2 ↙. (*b*) 20.1 ft. (*c*) 9.64 ft/s.
11.47 (*a*) 2.00 m/s ↑. (*b*) 2.00 m/s ↓. (*c*) 8.00 m/s ↑.
11.48 (*a*) 20.0 m/s^2 →, 6.67 m/s^2 ↓. (*b*) 13.33 m/s ↓, 13.33 m ↓.
11.49 (*a*) 30.0 ft/s ↑. (*b*) 15.00 ft/s ↑. (*c*) 45.0 ft/s ↑. (*d*) 30.0 ft/s ↑.
11.50 (*a*) 2.40 ft/s^2 ↑, 4.80 ft/s^2 ↓. (*b*) 12.00 ft/s ↑.
11.53 (*a*) 200 mm/s →. (*b*) 600 mm/s →. (*c*) 200 mm/s ←. (*d*) 400 mm/s →.
11.54 (*a*) 13.33 mm/s^2 ←, 20.0 mm/s^2 ←. (*b*) 13.33 mm/s^2 →. (*c*) 70.0 mm/s →, 440 mm →.
11.55 (*a*) 10.00 mm/s →, (*b*) 6.00 mm/s^2 →, 2.00 mm/s^2 ↑. (*c*) 175 mm ↑.
11.56 (*a*) 240 mm/s^2 ↓, 345 mm/s^2 ↑. (*b*) 130 mm/s →, 43.3 mm/s ↑. (*c*) 728 mm →.
11.57 (*a*) 2.00 in./s^2 ↑, 3.00 in/s^2 ↓. (*b*) 0.667 s. (*c*) 0.667 in. ↑.
11.58 (*a*) $(1 - 6t^2)/4$ in./s^2. (*b*) 9.06 in.
11.61 (*a*) Corresponding values of (t, v, x) are (0, −18 ft/s, 0), (4 s, −6 ft/s, −45 ft), (10 s, 30 ft/s, 24 ft), (20 s, −20 ft/s, 74 ft). (*b*) 12 ft/s, 74 ft, 176 ft., 20.0 ft/s
11.62 See Prob. 11.61 for plots. (*a*) 30.0 ft/s. (*b*) 30 ft/s, 114 ft.
11.63 (*a*) $0 < t < 10$ s, $a = 0$; $10 \text{ s} < t < 26$ s, $a = -5$ ft/s^2; $26 \text{ s} < t < 41$ s, $a = 0$; $41 \text{ s} < t < 46$ s, $a = 3$ ft/s^2; $t > 46$ s, $a = 0$; $x = -540$ ft at $t = 0$, $x = 60$ ft at $t = 10$ s, $x = 380$ ft at $t = 26$ s, $x = 80$ ft at $t = 41$ s, $x = 17.5$ ft at $t = 46$ s, $x = -2.5$ ft at $t = 50$ s. (*b*) 1383 ft. (*c*) 9.00 s, 49.5 s.
11.64 (*a*) Same as Prob. 11.63. (*b*) 420 ft. (*c*) 10.69 s, 40.0 s.
11.65 (*a*) 44.8 s. (*b*) 103.3 m/s^2 ↑.
11.66 207 mm/s
11.67 (*a*) 10.5 s. (*b*) v-t and x-t curves.
11.69 3.96 m/s^2.
11.70 (*a*) 0.600 s. (*b*) 0.200 m/s, 2.84 m.
11.71 9.39 s.
11.72 8.54 s, 58.3 mi/h.
11.73 1.525 s.
11.74 (*a*) 50.0 m/s, 1194 m. (*b*) 59.25 m/s.
11.77 (*a*) 18.00 s. (*b*) 178.8 m, (*c*) 34.7 km/h.
11.78 (*b*) 3.75 m.
11.79 (*a*) 2.00 s. (*b*) 1.200 ft/s, 0.600 ft/s.
11.80 (*a*) 5.01 min. (*b*) 19.18 mi/h.
11.83 (*a*) 2.96 s. (*b*) 224 ft.
11.84 (*a*) 163.0 in./s^2. (*b*) 114.3 in./s^2.
11.86 104 ft.
11.89 (*a*) 8.60 mm/s ⬎ 35.5°, 17.20 mm/s^2 ◿ 35.5°. (*b*) 33.4 mm/s ◿ 8.6°, 39.3 mm/s^2 ◿ 14.7°.
11.90 (*a*) 0, 159.1 m/s^2 ◺ 82.9°. (*b*) 6.28 m/s →, 157.9 m/s^2 ↓.
11.91 (*a*) 5.37 m/s. (*b*) $t = 2.80$ s, $x = -7.56$ m, $y = 5.52$ m, $\mathbf{v} = 5.37$ m/s^2 ◺ 63.4°.
11.92 (*a*) 2.00 in./s, 6.00 in./s. (*b*) For $v_{\min}$, $t = 2\text{N}\pi$ s, $x = 8\text{N}\pi$ in., $y = 2$ in., $\mathbf{v} = 2.00$ in./s → or 2.00 in./s ←. For $v_{\max}$, $t = (2\text{N} + 1)\pi$ s, $x = 4(2\text{N} + 1)\pi$, $y = 6$ in., $\mathbf{v} = 6.00$ in./s → or 6.00 in./s ←.
11.95 $\sqrt{R^2(1 + \omega_n^2 t^2) + c^2}$, $R\omega_n\sqrt{4 + \omega_n^2 t^2}$.
11.96 (*a*) 3.00 ft/s, 3.61 ft/s^2. (*b*) 3.82 s.
11.97 353 m.
11.98 (*a*) 15.50 m/s. (*b*) 5.12 m.
11.99 15.38 ft/s ≤ v_0 ≤ 35.0 ft/s.
11.100 (*a*) 70.4 mi/h ≤ v_0 ≤ 89.4 mi/h. (*b*) 6.89°, 4.29°.
11.101 (*a*) 2.87 m > 2.43 m. (*b*) 7.01 m from the net.
11.102 0.244 m ≤ h ≤ 0.386 m.
11.103 726 ft or 242 yd.
11.104 $0 \le d \le 1.737$ ft.
11.105 23.8 ft/s.
11.106 (*a*) 29.8 ft/s. (*b*) 29.6 ft/s.
11.107 10.64 m/s ≤ v_0 ≤ 14.48 m/s.
11.108 0.678 m/s ≤ v_0 ≤ 1.211 m/s.
11.111 (*a*) 4.90°. (*b*) 963 ft. (*c*) 16.24 s.
11.112 (*a*) 14.66°. (*b*) 0.1074 s.
11.113 (*a*) 10.38°. (*b*) 9.74°.
11.115 (*a*) 45.0°, 6.52 m. (*b*) 58.2°, 5.84 m.
11.117 (*a*) 1.540 m/s ◿ 38.6°. (*b*) 1.503 m/s ◿ 58.3°.
11.118 5.05 m/s ◺ 55.8°.
11.119 1.737 knots ⬎ 18.41°.
11.120 (*a*) 2.67 mi/h ◸ 12.97°. (*b*) 258 mi/h ◿ 76.4°. (*c*) 65 m ⬎ 40°.
11.123 (*a*) 8.53 in./s ◺ 54.1°. (*b*) 6.40 in./s^2 ◺ 54.1°.
11.124 (*a*) 7.01 in./s ◸ 60°. (*b*) 11.69 in./s^2 ◸ 60.6°.
11.125 (*a*) 0.835 mm/s^2 ◺ 75°. (*b*) 8.35 mm/s ◺ 75°.
11.126 (*a*) 0.958 m/s^2 ⬎ 23.6°. (*b*) 1.917 m/s ⬎ 23.6°.
11.127 10.54 ft/s ◸ 81.3°.
11.128 (*a*) 5.18 ft/s ◺ 15°. (*b*) 1.232 ft/s ◺ 15°.
11.129 17.49 km/h ◿ 59.0°.
11.130 15.79 km/h ⬎ 26.0°.
11.133 28.0 m/s.
11.134 (*a*) 250 m. (*b*) 82.9 km/h.
11.135 1815 ft.
11.136 59.9 mi/h.
11.137 (*a*) 20.0 mm/s^2. (*b*) 26.8 mm/s^2.
11.138 (*a*) 178.9 m. (*b*) 1.118 m/s^2.
11.139 2.53 ft/s^2.
11.141 15.95 ft/s^2.
11.143 (*a*) 281 m. (*b*) 209 m.
11.144 (*a*) 7.99 m/s ◿ 40°. (*b*) 3.82 m.
11.145 (*a*) 6.75 ft. (*b*) 0.1170 ft.
11.146 (*a*) 1.739 ft. (*b*) 27.9 ft.
11.147 $\rho_B = v_B^2/9v_A$.
11.148 18.17 m/s ◿ 4.04° and 18.17 m/s ⬎ 4.04°.
11.151 $(R^2 + c^2)/2\omega_n R$.

11.152 2.50 ft.
11.153 25.8×10^3 km/h.
11.154 12.56×10^3 km/h.
11.155 153.3×10^3 km/h.
11.156 92.9×10^6 mi.
11.157 885×10^6 mi.
11.158 1.606 h.
11.161 (*a*) $3\pi b\ \mathbf{e}_\theta$, $-4\pi^2 b\ \mathbf{e}_r$. (*b*) $\theta = 2N\pi$, N = 0, 1, 2, ...
11.162 (*a*) $2b\omega$, $4b\omega^2$. (*b*) $\rho = b$, a circle.
11.163 (*a*) $-(6\pi$ in./s$^2)\mathbf{e}_r$, $(80\ \pi$ in./s$^2)\mathbf{e}_\theta$. (*b*) 0.
11.165 (*a*) $(2\pi$ m/s$)\mathbf{e}_\theta$, $-(4\pi^2$ m/s$^2)\mathbf{e}_r$
(*b*) $-(\pi/2$ m/s$)\mathbf{e}_r + (\pi$ m/s$)\mathbf{e}_\theta$, $-(\pi^2/2$ m/s$^2)\mathbf{e}_r - (\pi^2$ m/s$^2)\mathbf{e}_\theta$.
11.166 (*a*) $2abt$, $2ab\sqrt{1 + 4b^2t^4}$. (*b*) $\rho = a$(circle).
11.169 $d\dot{\theta} \tan\beta \sec\beta/(\tan\beta \cos\theta - \sin\theta)^2$.
11.170 $v_0 \cos\beta\ (\tan\beta \cos\theta + \sin\theta)^2/h$.
11.171 185.7 km/h.
11.172 61.8 mi/h, 49.7°.
11.175 $(b\omega^2/\theta^3)\sqrt{4 + \theta^4}$.
11.176 $(1 + b^2)\ \omega^2 e^{b\theta}$.
11.180 $\tan^{-1}[R(2 + \omega_N^2 t^2)/c\sqrt{4 + \omega_N^2 t^2}]$
11.181 (*a*) $\theta_x = 90°$, $\theta_y = 123.7°$, $\theta_z = 33.7°$. (*b*) $\theta_x = 103.4°$, $\theta_y = 134.3°$, $\theta_z = 47.4°$.
11.182 (*a*) 1.00 s, 4.00 s. (*b*) 1.50 m, 24.5 m.
11.184 (*a*) -2.43×10^6 ft/s^2. (*b*) 1.366×10^{-3} s.
11.185 (*a*) 11.62 s, 69.7 ft. (*b*) 18.30 ft/s.
11.186 (*a*) 3.00 s. (*b*) 56.25 mm above its initial position.
11.187 $\mathbf{v}_A = 12.5$ mm/s ↑, $\mathbf{v}_B = 75$ mm/s ↓, $\mathbf{v}_C = 175$ mm/s ↓.
11.189 17.88 km/h ∠ 36.4°.
11.190 2.44 ft/s^2.
11.193 $\dot{r} = 120$ m/s, $\ddot{r} = 34.8$ m/s^2, $\dot{\theta} = -0.0900$ rad/s, $\ddot{\theta} = -0.0156$ rad/s^2.

CHAPTER 12

12.1 (*a*) 4.987 lb at 0°, 5.000 lb at 45°, 5.013 lb at 90°. (*b*) 5.000 lb at all latitudes. (*c*) 0.1554 lb · s^2/ft at all latitudes.
12.2 (*a*) 3.24 N. (*b*) 2.00 kg.
12.3 1.300×10^6 kg · m/s.
12.5 (*a*) 6.67 m/s. (*b*) 0.0755.
12.6 (*a*) 225 km/h. (*b*) 187.1 km/h.
12.7 0.242 mi.
12.8 (*a*) 135.3 ft. (*b*) 155.8 ft.
12.9 419 N to start and 301 N during sliding.
12.10 0.414 m/s^2 ↘ 15°.
12.11 (*a*) A: 2.49 m/s^2 →, B: 0.831 m/s^2 ↓. (*b*) 74.8 N.
12.12 (*a*) A: 0.698 m/s^2 →, B: 0.233 m/s^2 ↓. (*b*) 79.8 N.
12.15 (*a*) 0.986 m/s^2 ◺ 25°. (*b*) 51.7 N.
12.16 (*a*) 1.794 m/s^2 ◺ 25°. (*b*) 58.2 N.
12.17 (*a*) 0.997 ft/s^2 ∠ 15°, 1.619 ft/s^2 ∠ 15°.
12.19 *System 1:* (*a*) 10.73 ft/s^2. (*b*) 14.65 ft/s. (*c*) 1.864 s.
System 2: (*a*) 16.10 ft/s^2. (*b*) 17.94 ft/s. (*c*) 1.242 s.
System 3: (*a*) 0.749 ft/s^2. (*b*) 3.87 ft/s. (*c*) 26.7 s.
12.20 (*a*) 1.962 m/s^2 ↑. (*b*) 39.1 N.
12.21 (*a*) 6.63 m/s^2 ←. (*b*) 0.321 m →.
12.22 (*a*) 19.53 m/s^2 ∠ 65°. (*b*) 4.24 m/s^2 ◸ 65°.
12.24 $0.347\ m_0 v_0^2/F_0$.
12.26 $\sqrt{k/m}\ (\sqrt{l^2 + x_0^2} - l)$.
12.27 119.5 mi/h.
12.28 (*a*) 33.6 N. (*b*) $\mathbf{a}_A = 4.76$ m/s^2 →, $\mathbf{a}_B = 3.08$ m/s^2 ↓, $\mathbf{a}_C = 1.401$ m/s^2 ←.
12.29 (*a*) 36.0 N. (*b*) $\mathbf{a}_A = 5.23$ m/s^2 →, $\mathbf{a}_B = 2.62$ m/s^2 ↓. $\mathbf{a}_C = 0$.
12.30 (*a*) $\mathbf{a}_A = \mathbf{a}_B = \mathbf{a}_D = 2.76$ ft/s^2 ↓, $\mathbf{a}_C = 11.04$ ft/s^2 ↑.
(*b*) 18.80 lb.
12.31 (*a*) 24.2 ft/s ↓. (*b*) 17.25 ft/s ↑.
12.36 (*a*) 80.4 N. (*b*) 2.30 m/s.
12.37 (*a*) 49.9°. (*b*) 6.85 N.
12.38 8.25 ft/s.
12.40 2.77 m/s $< v <$ 4.36 m/s.
12.42 9.00 ft/s $< v_C <$ 12.31 ft/s.
12.43 2.42 ft/s $< v <$ 13.85 ft/s.
12.44 (*a*) 131.7 N. (*b*) 88.4 N.
12.45 (*a*) 553 N. (*b*) 659 N.
12.46 (*a*) 668 ft. (*b*) 120.0 lb↑.
12.47 (*a*) 6.95 ft/s^2 ↘ 20°. (*b*) 8.87 ft/s^2 ↘ 20°.
12.48 (*a*) 2.905 N. (*b*) 13.09°.
12.49 1126 N ◺ 25.6°.
12.50 24.1° ≤ θ ≤ 155.9°.
12.51 (*a*) 43.9°. (*b*) 0.390. (*c*) 78.8 km/h.
12.53 (*a*) 0.1858 W. (*b*) 10.28°.
12.55 468 mm.
12.56 2.36 m/s ≤ v ≤ 4.99 m/s.
12.57 (*a*) 0.1904, motion impending downward.
(*b*) 0.349, motion impending upward.
12.58 (*a*) Does not slide. 1.926 lb ◺ 80°.
(*b*) Slides downward. 1.123 lb ◺ 40°.
12.61 (*a*) 0.1834. (*b*) 10.39° for impending motion to the left., 169.6° for impending motion to the right.
12.62 (*a*) 2.98 ft/s. (*b*) 19.29° for impending motion to the left. 160.7° for impending motion to the right.
12.64 $1.054\sqrt{eV/mv_0^2}$.
12.65 1.333 l.
12.66 (*a*) $F_r = -10.73$ N, $F_\theta = 0.754$ N.
(*b*) $F_r = -4.44$ N, $F_\theta = 1.118$ N.
12.67 $F_r = 0.0523$ N, $F_\theta = 0.432$ N.
12.68 (*a*) $F_r = -1.217$ lb, $F_\theta = 0.248$ lb.
(*b*) $F_r = -0.618$ lb, $F_\theta = -0.0621$ lb.
12.69 (*a*) $mc^2(r_0 - kt)\ t^2$. (*b*) $mc(r_0 - 3kt)$.
12.70 2.00 s.
12.71 $\mathbf{P} = (5.76$ N$) \tan\theta \sec^3\theta$ ◺ θ
$\mathbf{Q} = (5.76$ N$) \tan^3\theta \sec^3\theta$ →
12.76 $v_r = v_0 \sin 2\theta/\sqrt{\cos 2\theta}$. $v_\theta = v_0\sqrt{\cos 2\theta}$.
12.79 (*a*) $r = (g\tau^2 R^2/4\pi^2)^{1/3}$. (*b*) $g = 24.8$ m/s^2.
12.80 (*a*) 35800 km and 22240 mi. (*b*) 3070 m/s and 10090 ft/s.
12.81 4.13×10^{21} lb · s^2/ft.
12.82 (*a*) 1 hr 57 min. (*b*) 3380 km.
12.84 (*a*) 86.9×10^{24} kg. (*b*) 436000 km.
12.86 (*a*) 5280 ft/s. (*b*) 8000 ft/s.
12.87 (*a*) 1551 m/s. (*b*) 15.8 m/s.
12.88 5000 m/s.
12.89 53 ft/s.
12.90 (*a*) At A $(a_A)_r = 0$, $(a_A)_\theta = 0$. (*b*) 1536 in./s^2. (*c*) 32.0 in./s.
12.91 (*a*) 24.0 in./s. (*b*) $a_r = -258$ in./s^2, $a_\theta = 0$. (*c*) -226 in./s^2.
12.98 10.42 km/s.
12.99 (*a*) 10.13 km/s. (*b*) 2.97 km/s.
12.103 (*a*) 26.3×10^3 ft/s. (*b*) 448 ft/s.
12.104 $\sqrt{2/(2 + \alpha)}$.
12.105 (*a*) 52.4×10^3 ft/s. (*b*) 1318 ft/s at A, 3900 ft/s at B.
12.108 98.0 h.
12.109 4.95 h.
12.110 54.0°.

12.112 5.31×10^9 km.
12.114 $\cos^{-1}[(1 - n\beta^2)/(1 - \beta^2)]$.
12.115 81.0 m/s.
12.116 (*a*) 14.37°. (*b*) 59.8 km/s.
12.118 Show . . . .
12.119 (*a*) $(r_1 - r_0)/(r_1 + r_0)$. (*b*) 609×10^{12} m.
12.120 Show . . . .
12.121 Derive . . . .
12.122 267 ft.
12.124 (*a*) 1.656 lb. (*b*) 20.8 lb.
12.125 (*a*) 20.49 ft/s^2 ◸ 30°. (*b*) 17.75 ft/s^2 →.
12.127 (*a*) 0.454, downward. (*b*) 0.1796, downward. (*c*) 0.218, upward.
12.128 (*a*) $F_r = -13.16$ lb, $F_\theta = 2.10$ lb. (*b*) $\mathbf{P} = 6.89$ lb ◺ 70°, $\mathbf{Q} = 14.00$ lb ◸ 40°.
12.129 $v_r = 2v_0 \sin 2\theta$, $v_\theta = v_0 \cos 2\theta$.
12.131 (*a*) $r = 1.250$ ft, $F_H = 0$. (*b*) $r = 0.871$ ft, $F_H = -2.69$ lb.
12.132 1.147.

CHAPTER 13

13.1 (*a*) 585 kJ. (*b*) 41.0 km/h.
13.2 4.54×10^9 ft · lb.
13.5 (*a*) 69.6 mi/h. (*b*) 56.9 mi/h.
13.6 (*a*) 32.8 mi/h. (*b*) 142.5 mi/h.
13.7 4.05 m/s.
13.8 2.99 m.
13.9 (*a*) 8.57 m/s ◿ 15°. (*b*) 5.30 m/s ◸ 15°.
13.10 (*a*) 8.70 m. (*b*) 4.94 m/s ◸ 15°.
13.13 6.71 m.
13.14 (*a*) 2.90 m/s. (*b*) 0.893 m.
13.15 (*a*) 124.1 ft. (*b*) $F_{AB} = 19.38$ kips (tension), $F_{BC} = 81.62$ kips (tension).
13.16 (*a*) 279 ft. (*b*) $F_{AB} = 19.38$ kips (compression), $F_{BC} = 8.62$ kips (compression).
13.21 (*a*) 2.34 m/s ←. (*b*) 235 mm.
13.22 (*a*) 45.7 J. (*b*) $T_A = 83.2$ N, $T_B = 60.3$ N.
13.23 (*a*) 10.36 ft/s ↓. (*b*) 17.94 ft/s ↓.
13.24 (*a*) 11.35 ft/s ◸ 23.6°. (*b*) 16.05 ft/s ◸ 23.6°.
13.25 1.190 m/s.
13.26 (*a*) 2.32 ft/s. (*b*) 2.39 ft/s.
13.27 (*a*) 0.222 ft. (*b*) Block moves to the right.
13.29 (*a*) 3.29 m/s. (*b*) 1.472 m.
13.31 (*a*) 0.750 in. ↓. (*b*) 8.51 in./s ↑ or ↓.
13.33 $0.759\sqrt{paA/m}$.
13.35 $1/[1 - (v_0^2 - v^2)/2g_m R_m]$.
13.36 1515 yd.
13.38 (*a*) 32.7 mm, 98.1 N ↑. (*b*) 30.4 mm, 104.9 N ↑.
13.39 (*a*) $\sqrt{3gl}$. (*b*) $\sqrt{2gl}$.
13.40 14.00°.
13.41 167.0 lb.
13.42 minimum = 167.0 lb, maximum = 1260 lb.
13.44 (*a*) 27.4°. (*b*) 3.81 ft.
13.46 (*a*) 20.2 ft · lb/s. (*b*) 118.7 ft · lb/s.
13.49 (*a*) 109.0 kW, 146.2 hp. (*b*) 530 kW, 711 hp.
13.50 (*a*) 2.75 kW. (*b*) 3.35 kW.
13.51 14.8 kN.
13.52 (*a*) 3000 lb. (*b*) 267 hp.
13.53 (*a*) 375 kW. (*b*) 5.79 km/h.
13.54 (*a*) 58.9 kW. (*b*) 52.9 kW.
13.55 (*a*) $k_1k_2/(k_1 + k_2)$. (*b*) $k_1 + k_2$.
13.56 (*a*) $x_0\sqrt{k_1k_2/m(k_1 + k_2)}$. (*b*) $x_0\sqrt{(k_1 + k_2)/m}$.
13.57 3.19 m/s → or 3.19 m/s ←.
13.58 (*a*) 3.34 ft/s. (*b*) 27.7 ft/s^2.
13.59 56.7 ft/s.
13.61 (*a*) 87.2 m/s. (*b*) 105.8 m/s.
13.62 (*a*) 1000 mm. (*b*) 4.42 m/s.
13.64 (*a*) 0.956 ft. (*b*) 7.85 ft/s.
13.65 (*a*) 43.5°. (*b*) 8.02 ft/s ↓.
13.68 0.269 m.
13.69 0.1744 m.
13.70 (*a*) 2.55 N. (*b*) 6.96 N.
13.71 (*a*) 8.15 N. (*b*) 2.94 N.
13.73 14.34 ft/s ←, 13.77 lb ↑.
13.74 (1): (*a*) 7.99 m/s. (*b*) 5.89 N ←.
(2): (*a*) 7.67 m/s. (*b*) 3.92 N ←.
13.75 (*a*) Loop 1: minimum $v_C = 3.84$ m/s > 3.5 m/s.
(*b*) Loop 2: $v_0 = 7.83$ m/s.
13.78 (*a*) $\cot\phi = 4.113/(12 - y)$.
(*b*) $\theta_x = 85.7°$, $\theta_y = 71.6°$, $\theta_z = 161.1°$.
13.80 (*b*) $V = -\ln xyz + C$.
13.81 (*a*) $\pi ka^2/4$. (*b*) 0.
13.82 (*a*) $F_x = x(x^2 + y^2 + z^2)^{-1/2}$, $F_y = y(x^2 + y^2 + z^2)^{-1/2}$, $F_z = z(x^2 + y^2 + z^2)$. (*b*) $a\sqrt{3}$.
13.85 (*a*) 90.46 J. (*b*) 2086 J.
13.86 57.5 MJ/kg.
13.87 15.65×10^3 mi/h.
13.88 450×10^3 ft · lb/lb.
13.89 (*a*) $mgR(1 - R/r)$. (*b*) $mgR^2/2r$. (*c*) $mgR(1 - R/2r)$.
13.90 (*a*) 33.9 MJ/kg. (*b*) 46.4 MJ/kg.
13.93 (*a*) 0.919 m/s. (*b*) 8.27 m/s.
13.94 (*a*) 7.35 m/s. (*b*) 11.02 m/s.
13.95 $v_r = 9.05$ ft/s, $v_\theta = 9.14$ ft/s.
13.96 (*a*) 25.3 in. (*b*) 7.58 ft/s.
13.97 maximum: 1.661 m, minimum: 0.338 m, maximum: 25.6 m/s, minimum: 5.21 m/s.
13.100 14.20 km/s.
13.101 29.8 m/s.
13.102 21.8×10^6 ft^2/s^2
13.103 (*a*) 16800 ft/s. (*b*) 32700 ft/s.
13.106 1555 m/s, 79.3°.
13.107 maximum: $r_0(1 + \sin\alpha)$, minimum: $r_0(1 - \sin\alpha)$
13.108 68.9°.
13.109 (*a*) 11.32×10^3 ft/s. (*b*) 13.68×10^3 ft/s.
13.110 58.9°.
13.111 (*a*) 31.5 m/s. (*b*) 1053 m/s.
13.116 (*b*) $v_{esc}\sqrt{\alpha/(1 + \alpha)} \le v_0 \le v_{esc}\sqrt{(1 + \alpha)/(2 + \alpha)}$.
13.118 (*a*) $h = r_{min}\, v_{max}$, $E/m = \frac{1}{2}v_{max}^2 - GM/r_{min}$.
13.119 (*a*) 3.40 s. (*b*) 25.5 s.
13.120 4 min 20 s.
13.121 (*a*) 3.11 s. (*b*) 1.493 s.
13.122 (*a*) 11.42 s. (*b*) $-(125.5$ m/s$)\mathbf{j} - (194.5$ m/s$)\mathbf{k}$.
13.123 (*a*) 2.49 s. (*b*) 12.24 s.
13.124 2.61 s.
13.126 0.260.
13.127 0.310.
13.129 (*a*) 14.78 s. (*b*) 693 lb (tension).
13.130 (*a*) 29.6 s. (*b*) 2500 lb (tension).
13.131 (*a*) 19.60 s. (*b*) 10.20 kN (compression).
13.132 (*a*) 3.92 m/s. (*b*) 39.2 N.
13.134 (*a*) 29.0 ft/s. (*b*) 77.3 ft/s.
13.135 (*a*) 77.3 ft/s. (*b*) 5.40 s.

13.136 (*a*) 5.00 s. (*b*) 49.9 ft/s. (*c*) 17.88 s.
13.137 (*a*) 7.00 s. (*b*) 10.99 ft/s. (*c*) 13.49 s.
13.139 8.18%.
13.140 6.21 *W*.
13.141 642 lb.
13.142 (*a*) 3730 lb. (*b*) 7450 lb.
13.145 (*a*) 1.333 km/h ←. (*b*) 0.1888 s.
13.146 (*a*) *A* was going faster. (*b*) 115.2 km/h.
13.147 (*a*) 8.51 km/h. (*b*) 6.67 N.
13.148 497 ft/s.
13.149 (*a*) *A*: $v_0\sqrt{L^2 - a^2}/2L$, *B*: $v_0\sqrt{L^2 + 3a^2}/2L$.
(*b*) $mv_0^2\,(L^2 - a^2)/4L^2$.
13.150 (*a*) 0.618 ft/s. (*b*) 3.04 ft/s.
13.151 (*a*) 1.000 m/s ↑. (*b*) 0.500 N · s ↑.
13.152 $mMv_0 \cos\theta/(m + M)$ →, $mv_0 \sin\theta$ ↑.
13.154 76.9 lb.
13.155 (*a*) $\mathbf{v}'_A = 0.363$ m/s ←, $\mathbf{v}'_B = 2.44$ m/s →. (*b*) 4.13 J.
13.157 0.800.
13.158 (*a*) $\mathbf{v}'_A = 10.38$ ft/s →, $\mathbf{v}'_B = 7.38$ ft/s →. (*b*) 0.0611 ft · lb.
13.159 *A*: 1.013 m/s ←, *B*: 0.338 m/s ←, *C*: 0.150 m/s ←.
13.160 (*a*) $v'_A = v_0(1 - e)/2$, $v'_B = v_0(1 + e)/2$.
(*b*) $v'_C = v_0(1 + e)^2/4$, $v'_B = v_0(1 - e)^2/4$.
(*c*) $v'_n = v_0(1 + e)^{(n-1)}/2^{(n-1)}$, (*d*) 0.881 v_0.
13.163 $0.728 \le e \le 0.762$.
13.165 $\mathbf{v}'_A = 6.37$ m/s ◸ 77.2°, $\mathbf{v}'_B = 1.802$ m/s ◿ 40°.
13.166 $\mathbf{v}'_A = 3.00$ m/s ◸ 40°, $\mathbf{v}'_B = 3.00$ m/s ◿ 40°.
13.167 (*a*) $\mathbf{v}_A = 0.848\,v_0$ ◹ 27.0°, $\mathbf{v}_B = 0.456\,v_0$ ◿ 57.6°.
13.168 (*a*) 70.0°. (*b*) 0.972 ft/s →.
13.169 0.857.
13.170 15.94 m.
13.173 (*a*) 22.5°. (*b*) 21.3°.
13.174 (*a*) 0.294 m. (*b*) 54.4 mm.
13.175 (*a*) 0.685 m for $e = 1$, 0.484 m for $e = 0$.
(*b*) 5.00 m/s → for $e = 1$, 2.50 m/s → for $e = 0$.
13.176 (*a*) $\mathbf{v}'_A = \mathbf{v}'_B = 0$. (*b*) $\mathbf{v}'_A = 1.201$ m/s →, $\mathbf{v}'_B = 0.400$ m/s →.
13.177 (*a*) 0.258. (*b*) 4.34 m/s.
13.178 (*a*) 0.0720 ft. (*b*) 72.2 lb/ft.
13.179 (*a*) $e = 1.000$. (*b*) 0.200 ft. (*e*) 0.263 ft.
13.183 (*a*) 2.90 m/s. (*b*) 100.5 J.
13.184 (*a*) 401 mm. (*b*) 4.10 N · s.
13.185 (*a*) 0.923. (*b*) 1.278 m.
13.188 $\mathbf{v}'_A = 1.093$ ft/s ←, $\mathbf{v}'_B = 3.28$ ft/s →.
13.190 1.688 ft · lb.
13.191 (*a*) 533 lb/ft. (*b*) 37.0 ft.
13.194 12900 ft/s.
13.196 65.0 KN.
13.197 0.707 *a*.
13.199 (*a*) 1.368 m/s. (*b*) 0.668 m. (*c*) 1.049 m.
13.200 $(1 + e)^2/4$.

CHAPTER 14

14.1 (*a*) 1.417 m/s →. (*b*) 1.417 m/s →.
14.2 (*a*) 10.00 kg. (*b*) 1.200 m/s →.
14.3 (*a*) 9.20 ft/s ←. (*b*) 9.37 ft/s ←.
14.4 (*a*) 2.80 ft/s ←. (*b*) 0.229 ft/s ←.
14.7 (*a*) *A*: 1.288 m/s ←, *B*: 0.312 m/s →, *C*: 1.512 m/s →.
(*b*) *A*: 0.956 m/s ←, *B*: 0.0296 m/s ←, *C*: 1.552 m/s →.
14.8 0.294 m/s ←.
14.9 $-(31.2\text{ kg} \cdot \text{m}^2/\text{s})\mathbf{i} - (64.8\text{ kg} \cdot \text{m}^2/\text{s})\mathbf{j} + (48.0\text{ kg} \cdot \text{m}^2/\text{s})\mathbf{k}$.
14.10 (*a*) $(0.600\text{ m})\mathbf{i} + (1.400\text{ m})\mathbf{j} + (1.525\text{ m})\mathbf{k}$.
(*b*) $-(26.0\text{ kg} \cdot \text{m/s})\mathbf{i} + (14.00\text{ kg} \cdot \text{m/s})\mathbf{j} + (14.00\text{ kg} \cdot \text{m/s})\mathbf{k}$.
(*c*) $-(29.5\text{ kg} \cdot \text{m}^2/\text{s})\mathbf{i} - (16.75\text{ kg} \cdot \text{m}^2/\text{s})\mathbf{j} + (3.20\text{ kg} \cdot \text{m}^2/\text{s})\mathbf{k}$.
14.13 (*a*) $v_x = -0.750$ ft/s, $v_z = 0.4375$ ft/s.
(*b*) $\mathbf{H}_O = -(3.39\text{ ft} \cdot \text{lb} \cdot \text{s})\mathbf{i}$.
14.14 (*a*) $v_x = 8.33$ ft/s, $v_z = 7.25$ ft/s. (*b*) $\mathbf{H}_O = -(4.51\text{ ft} \cdot \text{lb} \cdot \text{s})\mathbf{k}$.
14.15 $(4320\text{ ft})\mathbf{i} + (480\text{ ft})\mathbf{j} + (480\text{ ft})\mathbf{k}$.
14.16 $(400\text{ ft})\mathbf{i} - (258\text{ ft})\mathbf{j} + (32.0\text{ ft})\mathbf{k}$.
14.17 $(1004\text{ m})\mathbf{i} - (48.7\text{ m})\mathbf{j}$.
14.18 $(503\text{ m})\mathbf{i} - (547\text{ m})\mathbf{j}$.
14.21 (*a*) 8.50 ft/s. (*b*) 3.95 ft/s.
14.22 (*a*) 6.05 ft/s. (*b*) 6.81 ft/s.
14.23 $(26.0\text{ m})\mathbf{i} + (125.4\text{ m})\mathbf{k}$.
14.24 $v_A = 919$ m/s, $v_B = 717$ m/s, $v_C = 619$ m/s.
14.31 (*a*) 42.2 J. (*b*) 5.10 J.
14.32 (*a*) 264 J. (*b*) 352 J.
14.33 woman: 382 ft · lb, man: 447 ft · lb.
14.34 (*a*) 1116 ft · lb. (*b*) 623 ft · lb.
14.37 (*a*) $\mathbf{v}_B = m_A v_0/(m_A + m_B)$ →. (*b*) $h = m_B v_0^2/2g\,(m_A + m_B)$.
14.38 (*a*) $\mathbf{v}_A = 0.200\,v_0$ ←, $\mathbf{v}_B = 0.693\,v_0$ ◿ 30°,
$\mathbf{v}_C = 0.693\,v_0$ ◹ 30°. (*b*) $\mathbf{v}_A = 0.250\,v_0$ ◸ 60°,
$\mathbf{v}_B = 0.866\,v_0$ ◿ 30°, $\mathbf{v}_C = 0.433\,v_0$ ◹ 30°.
14.39 $v_A = 10.61$ ft/s, $v_B = 5.30$ ft/s, $v_C = 9.19$ ft/s.
14.40 $v_A = 7.50$ ft/s, $v_B = 9.19$ ft/s, $v_C = 9.19$ ft/s.
14.41 $\mathbf{v}_A = 4.11$ m/s ◿ 46.9°, $\mathbf{v}_B = 17.39$ m/s ◹ 16.7°.
14.42 $\mathbf{v}_A = 12.17$ m/s ◿ 25.3°, $\mathbf{v}_B = 9.17$ m/s ◹ 70.9°.
14.45 $(60.0\text{ m/s})\mathbf{i} + (60.0\text{ m/s})\mathbf{j} + (390\text{ m/s})\mathbf{k}$.
14.46 $x_{B_0} = 181.7$ mm, $y_{B_0} = 0$, $z_{B_0} = 139.4$ mm.
14.49 (*a*) 0.866 v_0. (*b*) 0.250 v_0. (*c*) 7.50%.
14.50 (*a*) 0.707 v_0. (*b*) 0.500 v_0. (*c*) 12.50%.
14.51 (*a*) $\mathbf{v}_A = 2.56$ m/s ↑, $\mathbf{v}_B = 4.24$ m/s ◹ 31.9°. (*b*) 2.34 m.
14.52 (*a*) $\mathbf{v}_0 = (2.4\text{ m/s})\mathbf{i} + (1.8\text{ m/s})\mathbf{j}$ (*b*) 600 mm. (*c*) 20.0 rad/s.
14.53 (*a*) $\mathbf{v}_B = 7.20$ ft/s ◿ 53.1°, $\mathbf{v}_C = 7.68$ ft/s →. (*b*) 42.0 in.
14.54 (*a*) $\mathbf{v}_A = 7.20$ ft/s ↓, $\mathbf{v}_B = 9.00$ ft/s ◿ 53.1°. (*b*) 74.0 in.
14.57 312 N.
14.58 4.18 m/s.
14.59 90.6 N ←.
14.60 (*a*) $F_x = 3280$ lb. (*b*) $F_z = 6450$ lb.
14.63 $\mathbf{C} = 161.7$ N ↑, $\mathbf{D}_x = 154.8$ N →, $\mathbf{D}_y = 170.2$ N ↑.
14.67 (*a*) 61.1 m/s. (*b*) 59.8 N ◺ 49.0°.
14.68 $C_x = 90.0$ N, $C_y = 2360$ N, $D_x = 0$, $D_y = 2900$ N.
14.69 36.9 kN.
14.70 251 lb/s.
14.71 (*a*) 9690 lb, 3.38 ft. (*b*) 6960 lb, 9.43 ft.
14.73 1.096 m.
14.74 7180 lb.
14.75 (*a*) 516 mi/h. (*b*) 391 mi/h.
14.77 (*a*) 15.47 kJ/s. (*b*) 0.323.
14.78 (*a*) 80.0 kJ/s. (*b*) 51.9 km/h.
14.79 (*a*) 15450 hp. (*b*) 28060 hp. (*c*) 0.551.
14.80 (*a*) 109.5 ft/s. (*b*) 3100 ft^3/s. (*c*) 43800 ft · lb/s
14.84 646 ft^3/s.
14.85 (*a*) $P = qv$.
14.86 *Case 1.* (*a*) 0.333 g ↓. (*b*) $0.817\sqrt{gl}$ ↓.
Case 2. (*a*) gy/l ↓. (*b*) $\sqrt{gl}$ ↓.
14.87 (*a*) $(m/l)(v^2 + gy)$. (*b*) $mg(1 - y/l)$ ↑.
14.88 (*a*) mgy/l. (*b*) $(m/l)\,[g(l - y) + v^2]$ ↑.
14.89 10.10 ft/s.
14.90 4.75 ft/s.
14.92 533 kg/s.
14.93 (*a*) 90.0 m/s^2. (*b*) 35.9×10^3 km/h.

14.94 (*a*) 31.9 m/s^2 ↑. (*b*) 240 m/s^2 ↑.
14.95 4410 lb.
14.96 3960 ft/s.
14.97 7930 m/s.
14.98 (*a*) 1800 m/s. (*b*) 9240 m/s.
14.99 186.8 km.
14.100 (*a*) 31.2 km. (*b*) 197.5 km.
14.106 (*a*) 5.20 km/h. (*b*) 4.00 km/h.
14.107 (*a*) $\mathbf{v}_A = \mathbf{v}_B = \mathbf{v}_C = 0.400$ mi/h →.
(*b*) $\mathbf{v}_A = \mathbf{v}_B = 1.68$ mi/h ←, $\mathbf{v}_C = 4.56$ mi/h →.
14.109 $\mathbf{v}_A = 15.38$ ft/s →, $\mathbf{v}_B = 5.13$ ft/s ←.
14.111 (*a*) qv_0 ←. (*b*) $\sqrt{2gh}$ ⦡ 30°.
14.112 1.712 kN ↑ at *C*, 2.29 kN ↑ at *D*.
14.113 414 rpm.
14.114 v^2/g.
14.115 (*a*) $m_0 + qt_L = m_0e^{qL/m_0v_0}$ (*b*) $v_L = v_0e^{-qL/m_0v_0}$

CHAPTER 15

15.1 (*a*) 0, 15.00 rad/s, −18.00 rad/s^2.
(*b*) −9.00 rad, −12.00 rad/s^2, 0.
15.2 1.000 s, 7.00 rad, −12.00 rad/s^2;
5.00 s, −25.0 rad, 12.00 rad/s^2.
15.3 (*a*) 0, 0, 0. (*b*) 6.00 rad, 4.71 rad/s, −3.70 rad/s^2.
15.4 1.243 rad, 3.33 rad/s, 4.79 rad/s^2.
15.5 (*a*) 0, 0.1000 rad/s, −0.0250 rad/s^2.
(*b*) 0.211 rad, 0.0472 rad/s, −0.01181 rad/s^2.
(*c*) 0.400 rad, 0, 0.
15.6 (*a*) 4.00 s^{-2}. (*b*) 5.29 rad/s.
15.9 (*a*) 12.73 rev. (*b*) ∞. (*c*) 18.42 s.
15.10 −(0.400 m/s)**i** − (1.400 m/s)**j** − (0.700 m/s)**k**,
(8.40 m/s^2)**i** + (3.30 m/s^2)**j** − (11.40 m/s^2)**k**.
15.11 −(0.400 m/s)**i** + (0.700 m/s)**k**,
−(2.00 m/s^2)**i** − (6.50 m/s^2)**j** − (3.00 m/s^2)**k**.
15.12 −(0.450 m/s)**i** − (1.200 m/s)**j** + (1.500 m/s)**k**,
(12.60 m/s^2)**i** + (7.65 m/s^2)**j** + (9.90 m/s^2)**k**.
15.13 (0.750 m/s)**i** + (1.500 m/s)**k**, (12.75 m/s^2)**i** +
(11.25 m/s^2)**j** + (3.00 m/s^2)**k**.
15.16 (*a*) 1525 ft/s, 0.1112 ft/s^2. (*b*) 1163 ft/s, 0.0852 ft/s^2. (*c*) 0, 0.
15.18 (*a*) 0.0600 m/s^2. (*b*) 0.0937 m/s^2. (*c*) 0.294 m/s^2.
15.19 (*a*) 6.00 m/s^2. (*b*) 9.98 m/s^2, (*c*) 60.0 m/s^2.
15.21 (*a*) 2.50 rad/s ↰, 1.500 rad/s^2 ↲. (*b*) 38.6 in./s^2 ⦢ 76.5°.
15.22 12.00 rad/s^2 ↲.
15.24 (*a*) 6.28 m/s, 1579 m/s^2. (*b*) 0.628 m/s, 15.80 m/s^2.
15.25 (*a*) 120 rpm, 275 rpm. (*b*) 23.7 m/s^2. ↑, 19.90 m/s^2 ↓.
15.27 (*a*) 10.00 rad/s ↰. (*b*) 7.50 m/s^2 ↓, 3.00 m/s^2 ↓.
(*c*) 4.00 m/s^2 ↓.
15.28 (*a*) 3.00 rad/s^2 ↲. (*b*) 4.00 s.
15.29 (*a*) 1.707 rad/s^2 ↰. (*b*) 6.83 rad/s ↰.
15.30 (*a*) 2.25 rev. (*b*) 1.710 m/s ↓, 3.11 m ↓.
(*c*) 849 mm/s^2 ∠ 32.0°.
15.31 (*a*) 1.152 m/s ↑, 2.30 m ↑. (*b*) 1.728 m/s ↓, 3.46 m ↓.
15.32 *Disk A*: 5.41 rad/s^2 ↰; *Disk B*: 1.466 rad/s^2 ↰.
15.33 (*a*) 10.39 s. (*b*) *Disk A*: 413 rpm ↳; *Disk B*: 248 rpm ↰.
15.35 (*a*) *Disk A*: 2.36 rad/s^2 ↳; *Disk B*: 4.19 rad/s^2 ↲. (*b*) 6.00 s.
15.36 $bv^2/2\pi r^3$ ↲.
15.37 $b\omega_0^2/2\pi$ →.
15.38 (*a*) 0.378 rad/s ↲. (*b*) 6.42 m/s ↑.
15.39 (*a*) 0.615 rad/s ↰. (*b*) 11.02 in./s ⦢ 15°.
15.40 (*a*) 2.26 rad/s ↰. (*b*) 1.840 m/s ⦡ 60°.
15.41 (*a*) 2.54 rad/s ↲. (*b*) 1.373 m/s ∠ 30°.
15.44 (*a*) 4.00 rad/s ↲. (*b*) −(4.00 in/s)**i**.
15.45 (*a*) (12.00 in./s)**i** + (8.00 in./s)**j**
(*b*) $x = 2.00$ in., $y = 3.00$ in.
15.46 (*a*) 2.00 rad/s ↲. (*b*) (120 mm/s)**i** + (660 mm/s)**j**.
15.48 (*a*) 105 rpm ↲. (*b*) 127.5 rpm ↲.
15.49 (*a*) 1.500. (*b*) 0.333 $\boldsymbol{\omega}_A$ ↰.
15.50 70 rpm ↲.
15.51 (*a*) 135.0 rpm ↲. (*b*) 105.0 rpm ↲.
15.52 (*a*) 48.0 rad/s ↲. (*b*) 3.39 m/s ∠ 45°.
15.55 (*a*) 60.0 rpm ↲, 37.7 in./s →. (*b*) 0, 50.3 in./s ←.
15.56 2.67 rad/s ↲, 34.4 in./s ←.
15.57 (*a*) 0, 39.3 rad/s ↰. (*b*) 6.28 m/s ↓, 0.
15.58 6.52 m/s ↓, 20.8 rad/s ↰.
15.60 (*a*) 0.1254 m/s ←. (*b*) 0.208 rad/s ↲.
15.61 (*a*) 3.02 rad/s ↲. (*b*) 0.657 rad/s ↰.
15.63 *Bar BD*: 0.955 rad/s ↰; *Bar DE*: 2.55 rad/s ↲.
15.64 *Bar BD*: 4.00 rad/s ↲; *Bar DE*: 6.67 rad/s ↰.
15.65 *Bar BD*: 5.20 rad/s ↲; *Bar DE*: 6.40 rad/s ↲.
15.66 (*a*) 3.33 rad/s ↰. (*b*) 2.00 m/s ⦢ 56.3°.
15.68 (*a*) 12.00 rad/s ↲. (*b*) 80.0 in./s →.
15.69 (*a*) 12.00 rad/s ↲. (*b*) 72.1 in./s ⦣ 56.3°.
15.70 *B*: 140.8 ft/s →; *C*: 0; *D*: 136.0 ft/s ∠ 15°; *E*: 99.6 ft/s ⦢ 45°.
15.71 (*a*) 338 mm/s ←, 0. (*b*) 710 mm/s ←, 2.37 rad/s ↲.
15.72 $\omega_C = (1 - r_A/r_C)\omega_{ABC}$.
15.73 (*a*) *C* lies 1.000 ft to right of *A*. (*b*) 4.00 in./s ↑.
15.74 $x = 0$, $z = 9.34$ ft.
15.75 (*a*) 50.0 mm to the right of the axle.
(*b*) 750 mm/s ↓, 1.950 m/s ↓.
15.76 (*a*) 25.0 mm to the right of axle. (*b*) 420 mm/s ↑.
15.77 (*a*) 12.00 rad/s ↲. (*b*) *Rack*: 2.40 m/s → *D*: 2.16 m/s ∠ 56.3°.
15.78 (*a*) 10.00 mm to the right of *A*. (*b*) 40.0 mm/s ↓.
(*c*) *DE*: unwrapped at 240 mm/s; *BF*: unwrapped at 120 mm/s.
15.79 (*a*) 20.0 mm to the right of *A*. (*b*) 80.0 mm/s ↓. (*c*) *DE*:
unwrapped at 240 mm/s; *BF*: unwrapped at 120 mm/s
15.82 (*a*) 12.00 rad/s ↰. (*b*) 3.90 m/s ⦣ 67.4°.
15.83 (*a*) 5.00 rad/s ↰. (*b*) 1.300 m/s ∠ 67.4°.
15.84 (*a*) 3.08 rad/s ↲. (*b*) 83.3 in./s ⦢ 73.9°.
15.85 (*a*) 0.467 rad/s ↰. (*b*) 3.49 ft/s ∠ 59.2°.
15.89 (*a*) 4.42 rad/s ↰. (*b*) 3.26 m/s ∠ 50°.
15.90 (*a*) 1.579 rad/s ↲. (*b*) 699 mm/s ∠ 78.3°.
15.92 (*a*) 22.0 in./s ∠ 79.6°. (*b*) 20.6 in./s ⦢ 20.5°.
15.93 (*a*) 2.79 in./s ∠ 36.7°. (*b*) 8.63 in./s ∠ 75.0°.
15.95 (*a*) 1260 mm/s ↑. (*b*) 1.250 rad/s ↰.
15.96 (*a*) 0.338 rad/s ↲. (*b*) 78.8 mm/s ←.
15.97 (*a*) *DE*: 2.50 rad/s ↲; *AB*: 1.176 rad/s ↲. (*b*) 29.4 m/s ←.
15.98 (*a*) *AB*: 2.00 rad/s ↲; *DE*: 5.00 rad/s ↰. (*b*) 24.0 in./s →.
15.99 *Space centroid*: quarter circle of 15 in. radius centered at *O*.
Body centrode: semi-circle of 7.5 in. radius centered midway
between *A* and *B*.
15.100 *Space centrode*: lower rack.
Body centrode: circumference of gear.
15.102 4.00 rad/s ↲, 6.67 rad/s ↰.
15.103 5.20 rad/s ↲, 6.40 rad/s ↲.
15.104 *B*: 140.8 ft/s →; *C*: 0; *D*: 136.0 ft/s ∠ 15.0°;
E: 99.6 ft/s ⦢ 45°.
15.105 (*a*) 0.900 m/s^2 →. (*b*) 1.800 m/s^2 ←.
15.106 (*a*) 0.600 m from *A*. (*b*) 0.200 m from *A*.
15.107 (*a*) 0.778 rad/s^2 ↲. (*b*) 4.22 m/s^2 ↑.
15.108 *A*: 7.00 ft/s^2 ↑; *B*: 0.200 ft/s^2 ↓.
15.109 (*a*) 2.88 m/s^2 ←. (*b*) 3.60 m/s^2 ←.
15.110 (*a*) 2.88 m/s^2 →. (*b*) 7.92 m/s^2 →.

15.111 (*a*) 5410 ft/s^2 $\downarrow$. (*b*) 5410 ft/s^2 $\uparrow$ (*c*) 5410 ft/s^2 $\measuredangle$ 60°.

15.112 (*a*) 96.0 rad/s^2 $\curvearrowleft$, 2.40 m/s^2 $\leftarrow$.
(*b*) 48.0 rad/s^2 $\curvearrowleft$, 1.200 m/s^2 $\leftarrow$.

15.113 (*a*) 300 mm/s^2 $\rightarrow$. (*b*) 247 mm/s^2 $\measuredangle$ 14.0°.

15.115 *A*: 56.6 in./s^2 $\measuredangle$ 58.0°; *B*: 80.0 in./s^2 $\uparrow$;
C: 172.2 in./s^2 $\measuredangle$ 25.8°.

15.116 *A*: 48.0 in./s^2 $\uparrow$; *B*: 85.4 in./s^2 $\measuredangle$ 69.4°;
C: 82.8 in./s^2 $\measuredangle$ 65.0°.

15.118 (*a*) 13.35 in./s^2 $\measuredangle$ 61.0°. (*b*) 12.62 in./s^2 $\measuredangle$ 64.0°.

15.119 (*a*) 92.5 in./s^2. (*b*) 278 in./s^2.

15.120 (*a*) 59.8 m/s^2 $\uparrow$. (*b*) 190.6 in./s^2 $\uparrow$.

15.121 *D*: 1558 m/s^2 $\measuredangle$ 45°; *E*: 337 m/s^2 $\measuredangle$ 45°.

15.122 (*a*) 1218 in./s^2 $\leftarrow$. (*b*) 993 in./s^2 $\leftarrow$.

15.125 148.3 m/s^2 $\downarrow$.

15.126 296 m/s^2 $\uparrow$.

15.127 (*a*) 1080 rad/s^2 $\curvearrowright$. (*b*) 460 ft/s^2 $\measuredangle$ 64.9°.

15.128 (*a*) 432 rad/s^2 $\curvearrowleft$. (*b*) 272 ft/s^2 $\measuredangle$ 60.3°.

15.129 1.745 m/s^2 $\measuredangle$ 68.2°.

15.130 (*a*) 7.20 rad/s^2. (*b*) 1.296 m/s^2 $\leftarrow$.

15.132 9.60 m/s^2 $\rightarrow$.

15.133 (*a*) 10.75 rad/s^2 $\curvearrowleft$. (*b*) 2.30 rad/s^2 $\curvearrowleft$.

15.135 (*a*) 8.15 rad/s^2 $\curvearrowleft$. (*b*) 0.896 rad/s^2.

15.138 $v_B \sin \beta/l \cos \theta$.

15.139 $(v_B \sin \beta/l)^2 \sin \theta/\cos^3 \theta$

15.140 $b\omega \cos \theta$, $b\alpha \cos \theta - b\omega^2 \sin \theta$.

15.141 $bv_A/(b^2 + x_A^2)$ $\curvearrowleft$, $2b_A x_A v_A^2/(b^2 + x_A^2)^2$

15.143 $v[1 - \cos (vt/r)]$, $v \sin (vt/r)$.

15.146 $v_0 \sin^2 \theta/r \cos \theta$ $\curvearrowleft$.

15.147 $(v_0/r)^2 (1 + \cos^2 \theta) + \tan^3 \theta$ $\curvearrowleft$.

15.149 $(R\omega \sin \omega t)\mathbf{j}$, $(R\omega^2 \cos \omega t)\mathbf{j}$

15.150 (*a*) 1.815 rad/s $\curvearrowright$. (*b*) 16.42 in./s $\measuredangle$ 20°.

15.151 (*a*) 5.16 rad/s $\curvearrowright$. (*b*) 1.339 in./s $\measuredangle$ 60°.

15.152 *AP*: 4.68 rad/s $\curvearrowleft$; *BE*: 1.415 rad/s $\curvearrowleft$.

15.153 *AD*: 2.52 rad/s $\curvearrowright$; *BP*: 1.299 rad/s $\curvearrowright$.

15.156 (*a*) $\mathbf{v}_{H/AE} = l\omega \leftarrow$, $\mathbf{v}_{H/BD} = 0$. (*b*) $\mathbf{v}_{H/AE} = 0.577\, l\omega \measuredangle$ 30°,
$\mathbf{v}_{H/BD} = 0.577\, l\omega \measuredangle$ 30°.

15.157 $\mathbf{v}_{H/AE} = 0.299\, l\omega \measuredangle$ 45°, $\mathbf{v}_{H/BD} = 0.816\, l\omega \measuredangle$ 15°.

15.160 (*a*) 0.520 m/s $\measuredangle$ 82.6°. (*b*) 50.0 mm/s^2 $\measuredangle$ 9.8°.

15.161 (*a*) 0.520 m/s $\measuredangle$ 37.4°. (*b*) 50.0 mm/s^2 $\measuredangle$ 69.8°.

15.162 (*a*) $-(51.0 \text{ in./s})\mathbf{j} + (108.0 \text{ in./s})\mathbf{k}$. (*b*) $-(51.0 \text{ in./s})\mathbf{j}$.

15.163 (*a*) $(96.0 \text{ in./s})\mathbf{i} - (108.0 \text{ in./s})\mathbf{k}$. (*b*) $(96.0 \text{ in./s})\mathbf{i}$.

15.165 0.0234 m/s^2 west.

15.166 (*a*) 68.1 in./s^2 $\measuredangle$ 21.5°. (*b*) 101.4 in./s^2 $\measuredangle$ 3.2°.

15.167 (*a*) 95.2 in./s^2 $\measuredangle$ 48.3°. (*b*) 57.5 in./s $\measuredangle$ 64.3°.

15.168 *Link 1:* 303 mm/s^2 $\rightarrow$; *Link 2:* 168.5 mm/s^2 $\measuredangle$ 57.7°.

15.169 *Link 3:* 483 mm/s^2 $\leftarrow$; *Link 4:* 168.5 mm/s^2 $\measuredangle$ 57.7°.

15.171 392 in./s^2 $\measuredangle$ 4.05°.

15.174 (*a*) $\mathbf{a}_A = 0.621$ m/s^2 $\uparrow$. (*b*) $\mathbf{a}_B = 1.733$ m/s^2 $\measuredangle$ 53.9°.
(*c*) $\mathbf{a}_C = 2.62$ m/s^2 $\measuredangle$ 67.6°.

15.175 1.500 rad/s $\curvearrowleft$, 7.79 rad/s^2 $\curvearrowleft$.

15.176 6.00 rad/s $\curvearrowleft$, 62.4 rad/s^2 $\curvearrowright$.

15.177 43.0 rad/s^2 $\curvearrowright$.

15.178 47.0 rad/s^2 $\curvearrowright$.

15.181 (*a*) 2.40 rad/s $\curvearrowright$, 34.6 rad/s^2 $\curvearrowright$.
(*b*) 1.342 m/s $\measuredangle$ 63.4°, 9.11 m/s^2 $\measuredangle$ 18.4°.

15.182 (*a*) 3.61 rad/s $\curvearrowleft$. (*b*) 86.6 in./s $\measuredangle$ 30°. (*c*) 563 in./s^2 $\measuredangle$ 46.1°.

15.183 (*a*) 3.61 rad/s $\curvearrowright$. (*b*) 86.6 in./s $\measuredangle$ 30°. (*c*) 563 in./s^2 $\measuredangle$ 46.1°.

15.184 (*a*) $(1.500 \text{ rad/s})\mathbf{i} - (3.00 \text{ rad/s})\mathbf{j} - (2.50 \text{ rad/s})\mathbf{k}$.
(*b*) $(27.0 \text{ in./s})\mathbf{i} - (14.00 \text{ in./s})\mathbf{j} + (33.0 \text{ in./s})\mathbf{k}$.

15.185 (*a*) $-(1.500 \text{ rad/s})\mathbf{i} - (0.750 \text{ rad/s})\mathbf{j} - (1.000 \text{ rad/s})\mathbf{k}$.
(*b*) $(9.00 \text{ in./s})\mathbf{i} - (14.00 \text{ in./s})\mathbf{j} - (3.00 \text{ in./s})\mathbf{k}$.

15.186 (*a*) $(0.480 \text{ rad/s})\mathbf{i} - (1.600 \text{ rad/s})\mathbf{j} + (0.600 \text{ rad/s})\mathbf{k}$.
(*b*) $(400 \text{ mm/s})\mathbf{i} + (300 \text{ mm/s})\mathbf{j} + (480 \text{ mm/s})\mathbf{k}$.

15.187 (*a*) $-(0.400 \text{ rad/s})\mathbf{j} - (0.360 \text{ rad/s})\mathbf{k}$.
(*b*) $(100 \text{ mm/s})\mathbf{i} - (90 \text{ mm/s})\mathbf{j} + (120 \text{ mm/s})\mathbf{k}$.

15.188 $-(9.87 \text{ rad/s}^2)\mathbf{k}$.

15.189 $(118.4 \text{ rad/s}^2)\mathbf{i}$.

15.190 (*a*) $\omega_1\mathbf{j} + (R/r)\omega_1\mathbf{k}$. (*b*) $(R/r)\omega_1^2\mathbf{i}$.

15.193 (*a*) $-(0.600 \text{ m/s})\mathbf{i} + (0.750 \text{ m/s})\mathbf{j} - (0.600 \text{ m/s})\mathbf{k}$.
(*b*) $-(6.15 \text{ m/s}^2)\mathbf{i} - (3.00 \text{ m/s}^2)\mathbf{j}$.

15.194 (*a*) $-(20.0 \text{ rad/s}^2)\mathbf{i}$. (*b*) $-(4.00 \text{ ft/s}^2)\mathbf{i} + (10.00 \text{ ft/s}^2)\mathbf{k}$.
(*c*) $-(10.25 \text{ ft/s}^2)\mathbf{j}$.

15.195 $-(3.46 \text{ ft/s}^2)\mathbf{i} - (5.13 \text{ ft/s}^2)\mathbf{j} + (8.66 \text{ ft/s}^2)\mathbf{k}$.

15.196 (*a*) $-(0.1745 \text{ rad/s})\mathbf{i} - (0.524 \text{ rad/s})\mathbf{j}$. (*b*) $-(0.0914 \text{ rad/s}^2)\mathbf{k}$.
(*c*) $-(1.818 \text{ m/s})\mathbf{i} + (0.605 \text{ m/s})\mathbf{j} - (3.49 \text{ m/s})\mathbf{k}$,
$(0.366 \text{ m/s}^2)\mathbf{i} - (0.0609 \text{ m/s}^2)\mathbf{j} - (1.055 \text{ m/s}^2)\mathbf{k}$.

15.198 (*a*) $(8.00 \text{ rad/s})\mathbf{i}$. (*b*) $-(19.20 \text{ rad/s}^2)\mathbf{k}$.
(*c*) $-(1.103 \text{ m/s}^2)\mathbf{i} - (2.005 \text{ m/s}^2)\mathbf{j}$.

15.199 (*a*) $(0.750 \text{ rad/s})\mathbf{i} + (1.500 \text{ rad/s})\mathbf{j}$
(*b*) $(300 \text{ mm/s})\mathbf{i} - (150 \text{ mm/s})\mathbf{j}$
(*c*) $(60 \text{ mm/s})\mathbf{i} - (30 \text{ mm/s})\mathbf{j} - (90 \text{ mm/s})\mathbf{k}$.

15.200 (*a*) $(1.125 \text{ rad/s}^2)\mathbf{k}$.
(*b*) $-(225 \text{ mm/s}^2)\mathbf{i} + (180 \text{ mm/s}^2)\mathbf{j} - (112.5 \text{ mm/s}^2)\mathbf{k}$.

15.202 $(210 \text{ mm/s})\mathbf{k}$.

15.203 $(40.0 \text{ mm/s})\mathbf{k}$.

15.204 $-(30.0 \text{ in./s})\mathbf{j}$.

15.205 $(45.7 \text{ in./s})\mathbf{j}$.

15.206 $(12.78 \text{ mm/s})\mathbf{j}$.

15.207 $(4.66 \text{ mm/s})\mathbf{j}$.

15.210 $(\omega_1/\cos 25°)\ (-\sin 25°\mathbf{j} + \cos 25°\ \mathbf{k})$

15.211 $\omega_1/\cos 25°\ (-\sin 25°\mathbf{j} + \cos 25°\ \mathbf{k})$

15.212 (*a*) $(0.240 \text{ rad/s})\mathbf{i} + (0.080 \text{ rad/s})\mathbf{j} - (1.080 \text{ rad/s})\mathbf{k}$.
(*b*) $(40.0 \text{ mm/s})\mathbf{k}$.

15.213 (*a*) $-(0.348 \text{ rad/s})\mathbf{i} + (0.279 \text{ rad/s})\mathbf{j} + (1.089 \text{ rad/s})\mathbf{k}$.
(*b*) $-(30.0 \text{ in./s})\mathbf{j}$.

15.214 $-(510 \text{ mm/s}^2)\mathbf{k}$.

15.216 $-(45.0 \text{ in./s}^2)\mathbf{j}$.

15.217 $(205 \text{ in./s}^2)\mathbf{j}$.

15.218 $-(9.51 \text{ mm/s}^2)\mathbf{j}$.

15.219 $-(8.76 \text{ mm/s}^2)\mathbf{j}$.

15.220 (*a*) $(72.0 \text{ in./s})\mathbf{i} + (30.0 \text{ in./s})\mathbf{j} - (48.0 \text{ in./s})\mathbf{k}$.
(*b*) $-(288 \text{ in./s}^2)\mathbf{i} - (864 \text{ in./s}^2)\mathbf{k}$.

15.221 (*a*) $(30.0 \text{ in./s})\mathbf{i} - (16.0 \text{ in./s})\mathbf{j} - (16.0 \text{ in./s})\mathbf{k}$,
$-(48.0 \text{ in./s}^2)\mathbf{i} + (96.0 \text{ in./s}^2)\mathbf{k}$.
(*b*) $(30.0 \text{ in./s})\mathbf{i} - (16.0 \text{ in./s})\mathbf{j}$; $(96.0 \text{ in./s}^2)\mathbf{k}$.

15.222 (*a*) $(0.750 \text{ m/s})\mathbf{i} + (1.299 \text{ m/s})\mathbf{j} - (1.732 \text{ m/s})\mathbf{k}$.
(*b*) $(27.1 \text{ m/s}^2)\mathbf{i} + (5.63 \text{ m/s}^2)\mathbf{j} - (15.00 \text{ m/s}^2)\mathbf{k}$.

15.223 (*a*) $(0.75 \text{ m/s})\mathbf{i} + (1.299 \text{ m/s})\mathbf{j} - (1.732 \text{ m/s})\mathbf{k}$.
(*b*) $-(28.6 \text{ m/s}^2)\mathbf{i} + (3.21 \text{ m/s}^2)\mathbf{j} - (10.67 \text{ m/s}^2)\mathbf{k}$.

15.226 $-(1.215 \text{ m/s})\mathbf{i} + (1.620 \text{ m/s})\mathbf{k}$; $-(30.4 \text{ m/s}^2)\mathbf{k}$.

15.227 $-(1.080 \text{ m/s})\mathbf{k}$; $(19.44 \text{ m/s}^2)\mathbf{i} - (12.96 \text{ m/s}^2)\mathbf{k}$.

15.228 $-(1.215 \text{ m/s})\mathbf{i} - (1.080 \text{ m/s})\mathbf{j} + (1.620 \text{ m/s})\mathbf{k}$;
$(19.44 \text{ m/s}^2)\mathbf{i} - (30.4 \text{ m/s}^2)\mathbf{j} - (12.96 \text{ m/s}^2)\mathbf{k}$.

15.229 $-(1.215 \text{ m/s})\mathbf{i} - (1.080 \text{ m/s})\mathbf{j} + (1.620 \text{ m/s})\mathbf{k}$;
$(25.5 \text{ m/s}^2)\mathbf{i} - (25.0 \text{ m/s}^2)\mathbf{j} - (21.1 \text{ m/s}^2)\mathbf{k}$.

15.230 (*a*) $(30.0 \text{ in./s})\mathbf{i} - (16.0 \text{ in./s})\mathbf{j} - (16.0 \text{ in./s})\mathbf{k}$;
$-(75.0 \text{ in./s}^2)\mathbf{i} - (8.0 \text{ in./s})\mathbf{j} + (32.0 \text{ in./s})\mathbf{k}$.
(*b*) $(30.0 \text{ in./s})\mathbf{i} - (16.0 \text{ in./s})\mathbf{j}$; $-(75.0 \text{ in./s}^2)\mathbf{i} +$
$(40.0 \text{ in./s}^2)\mathbf{j} + (96.0 \text{ in./s}^2)\mathbf{k}$.

15.232 $-(41.6 \text{ in./s}^2)\mathbf{i} - (61.5 \text{ in./s}^2)\mathbf{j} + (103.9 \text{ in./s}^2)\mathbf{k}$.

15.234 (*a*) $-(0.270 \text{ rad/s}^2)\mathbf{i}$. (*b*) $(6.24 \text{ in./s})\mathbf{i} - (3.60 \text{ in./s})\mathbf{j} - (16.80 \text{ in./s})\mathbf{k}$. (*c*) $-(11.70 \text{ in./s}^2)\mathbf{i} - (2.81 \text{ in./s}^2)\mathbf{j} - (7.48 \text{ in./s}^2)\mathbf{k}$.
15.235 $(0.600 \text{ m/s})\mathbf{j} - (0.585 \text{ m/s})\mathbf{k}$; $-(4.76 \text{ m/s}^2)\mathbf{i}$.
15.236 $(0.600 \text{ m/s})\mathbf{j} - (0.225 \text{ m/s})\mathbf{k}$; $-(0.675 \text{ m/s}^2)\mathbf{i} + (3.00 \text{ m/s}^2)\mathbf{j} - (3.60 \text{ m/s}^2)\mathbf{k}$.
15.237 $(4.33 \text{ ft/s})\mathbf{i} - (6.18 \text{ ft/s})\mathbf{j} + (5.30 \text{ ft/s})\mathbf{k}$; $(2.65 \text{ ft/s}^2)\mathbf{i} - (2.64 \text{ ft/s}^2)\mathbf{j} - (3.25 \text{ ft/s}^2)\mathbf{k}$.
15.240 $-(5.04 \text{ m/s})\mathbf{i} - (1.200 \text{ m/s})\mathbf{k}$; $-(9.60 \text{ m/s}^2)\mathbf{i} - (25.9 \text{ m/s}^2)\mathbf{j} + (57.6 \text{ m/s}^2)\mathbf{k}$.
15.241 $-(0.720 \text{ m/s})\mathbf{i} - (1.200 \text{ m/s})\mathbf{k}$; $-(9.60 \text{ m/s}^2)\mathbf{i} + (25.9 \text{ m/s}^2)\mathbf{j} - (11.52 \text{ m/s}^2)\mathbf{k}$.
15.242 $(3.00 \text{ in./s})\mathbf{i} - (1.800 \text{ in./s})\mathbf{j}$; $-(13.50 \text{ in./s}^2)\mathbf{i} + (9.00 \text{ in./s}^2)\mathbf{j} + (8.64 \text{ in./s}^2)\mathbf{k}$.
15.243 $(9.00 \text{ in./s})\mathbf{i} - (7.80 \text{ in./s})\mathbf{j} + (7.20 \text{ in./s})\mathbf{k}$; $(9.00 \text{ in./s}^2)\mathbf{i} - (22.1 \text{ in./s}^2)\mathbf{j} - (5.76 \text{ in./s}^2)\mathbf{k}$.
15.244 (*a*) $(0.610 \text{ m/s})\mathbf{k}$; $-(0.880 \text{ m/s}^2)\mathbf{i} + (1.170 \text{ m/s}^2)\mathbf{j}$. (*b*) $(0.520 \text{ m/s})\mathbf{i} - (0.390 \text{ m/s})\mathbf{j} - (1.000 \text{ m/s})\mathbf{k}$; $-(4.00 \text{ m/s}^2)\mathbf{i} - (3.25 \text{ m/s}^2)\mathbf{k}$.
15.245 (*a*) $(1.390 \text{ m/s})\mathbf{k}$; $(7.12 \text{ m/s}^2)\mathbf{i} - (1.170 \text{ m/s}^2)\mathbf{j}$. (*b*) $(0.520 \text{ m/s})\mathbf{i} - (0.390 \text{ m/s})\mathbf{j} + 1.000 \text{ m/s})\mathbf{k}$; $(4.00 \text{ m/s}^2)\mathbf{i} - (3.25 \text{ m/s}^2)\mathbf{k}$.
15.248 (*a*) 51.3 in./s^2 ↓. (*b*) 184.9 in./s^2 ∠ 16.1°.
15.249 (*a*) −1.824 rad/s^2. (*b*) 103.3 s.
15.250 (*a*) $(0.450 \text{ m/s})\mathbf{k}$, $(4.05 \text{ m/s}^2)\mathbf{i}$. (*b*) $-(1.350 \text{ m/s})\mathbf{k}$, $-(6.75 \text{ m/s}^2)\mathbf{i}$.
15.252 (*a*) 37.5 in./s →. (*b*) 187.5 in./s^2 ↑.
15.254 49.4 m/s^2 ↘ 26.0°.
15.256 $(7.84 \text{ in./s})\mathbf{k}$.
15.257 (*a*) 0.1749 rad/s ↰. (*b*) 66.2 mm/s ↖ 25°.
15.259 $(0.325 \text{ m/s})\mathbf{i} + (0.1875 \text{ m/s})\mathbf{j} - (0.313 \text{ m/s})\mathbf{k}$, $-(2.13 \text{ m/s}^2)\mathbf{i} + (0.974 \text{ m/s}^2)\mathbf{j} - (3.25 \text{ m/s}^2)\mathbf{k}$.

CHAPTER 16

16.1 (*a*) 3.43 N ∠ 20°. (*b*) 24.4 N ↖ 73.4°.
16.2 3.57 m/s^2 ←.
16.3 6.84 ft/s^2.
16.4 (*a*) 13.42 ft/s^2 →. (*b*) 8.67 lb.
16.5 (*a*) 25.8 ft/s^2. (*b*) 12.27 ft/s^2. (*c*) 13.32 ft/s^2.
16.6 (*a*) 36.8 ft. (*b*) 42.3 ft.
16.7 (*a*) 5.00 m/s^2 →. (*b*) $0.311 \text{ m} \le h \le 1.489 \text{ m}$.
16.8 (*a*) 2.55 m/s^2 →. (*b*) $h \le 1.047$ m.
16.11 (*a*) $0.337\,g$ ∠ 30°. (*b*) $h/d = 4.00$.
16.12 (*a*) $0.252\,g$ ↗ 30°. (*b*) $h/d = 4.00$.
16.13 435 lb.
16.14 (*a*) 4.91 m/s^2 ↗ 30°. (*b*) *AD*: 31.0 N; *BE*: 11.43 N.
16.16 (*a*) 2.54 m/s^2 ↗ 15°. (*b*) *AC*: 6.01 N tension; *BD*: 22.4 N tension.
16.17 *CF*: 4.05 lb compression; *BE*: 14.33 lb compression.
16.20 (*a*) 30.6 ft/s^2 ↘ 84.1°. (*b*) $\mathbf{B} = 1.285$ lb ∠ 30°, $\mathbf{A} = 0.505$ lb ∠ 30°.
16.22 $|\text{V}|_{\max} = 40.3$ lb, $|\text{M}|_{\max} = 25.2$ lb · ft.
16.25 87.8 lb · ft.
16.26 5230 revolutions.
16.27 20.4 rad/s^2 ↲.
16.28 32.7 rad/s^2 ↰.
16.29 59.4 s.
16.30 93.5 revolutions.
16.34 (1): (*a*) 8.00 rad/s^2 ↰. (*b*) 14.61 rad/s ↰.
(2): (*a*) 6.74 rad/s^2 ↰. (*b*) 13.41 rad/s ↰.
(3): (*a*) 4.24 rad/s^2 ↰. (*b*) 10.64 rad/s ↰.
(4): (*a*) 5.83 rad/s^2 ↰. (*b*) 8.82 rad/s ↰.
16.36 (*a*) 7.63 rad/s^2 ↲. (*b*) 2.78 lb ↗.
16.37 (*a*) 1.255 ft/s^2 ↓. (*b*) 0.941 ft/s^2 ↑.
16.38 (*a*) 1.971 ft/s^2 ↑. (*b*) 1.971 ft/s^2 ↓.
16.39 (*a*) $\boldsymbol{\alpha}_A = 12.50$ rad/s^2 ↰, $\boldsymbol{\alpha}_B = 33.3$ rad/s^2 ↰. (*b*) *A*: 320 rpm ↲, *B*: 320 rpm ↰.
16.40 (*a*) $\boldsymbol{\alpha}_A = 12.50$ rad/s^2 ↰, $\boldsymbol{\alpha}_B = 33.3$ rad/s^2 ↰. (*b*) *A*: 90.0 rpm ↰, *B*: 120.0 rpm ↲.
16.41 (*a*) Slipping occurs. (*b*) $\boldsymbol{\alpha}_A = 61.8$ rad/s^2 ↰. $\boldsymbol{\alpha}_B = 9.66$ rad/s^2 ↲.
16.42 (*a*) No slipping. (*b*) $\boldsymbol{\alpha}_A = 15.46$ rad/s^2 ↰. $\boldsymbol{\alpha}_B = 7.73$ rad/s^2 ↲.
16.48 (*a*) *A*: 18.40 ft/s^2. (*b*) 9.20 ft/s^2 ←.
16.49 (*a*) 12.00 in. from *A*. (*b*) 9.20 ft/s^2 →.
16.50 (*a*) 2.50 m/s^2 →. (*b*) 0.
16.51 (*a*) 3.75 m/s^2 →. (*b*) 1.25 m/s^2 ←.
16.55 *A*: 0.885 m/s^2 ↓, *B*: 2.60 m/s^2 ↑.
16.56 *A*: 0.273 m/s^2 ↓, *B*: 2.01 m/s^2 ↓.
16.57 *A*: 359 lb, *B*: 312 lb.
16.58 *A*: 275 lb, *B*: 361 lb.
16.59 (*a*) 0.741 rad/s^2 ↰. (*b*) 0.857 m/s^2 ↑.
16.60 (*a*) 2800 N. (*b*) 15.11 rad/s^2 ↲.
16.63 (*a*) $3.00\,g/L$ ↲. (*b*) $1.000\,g$ ↑. (*c*) $2.00\,g$ ↓.
16.64 (*a*) $1.000\,g/\text{L}$ ↲. (*b*) 0. (*c*) $1.000\,g$ ↓
16.65 (*a*) $1.000\,g/\text{L}$ ↲. (*b*) $0.866\,g$ ←. (*c*) $1.323\,g$ ∠ 49.1°.
16.66 (*a*) $0.500\,g$ ↑. (*b*) $1.500\,g$ ↓
16.67 (*a*) 0. (*b*) $1.000\,g$ ↓.
16.69 (*a*) 1.597 s. (*b*) 9.86 ft/s. (*c*) 19.85 ft.
16.70 (*a*) 1.863 s. (*b*) 9.00 ft/s. (*c*) 22.4 ft.
16.72 (*a*) v_0/r ↰. (*b*) $v_0/\mu_k g$. (*c*) $v_0^2/2\mu_k g$.
16.76 (*a*) 12.08 rad/s^2 ↲. (*b*) $\mathbf{A}_x = 0.750$ lb ←, $\mathbf{A}_y = 4.00$ lb ↑.
16.77 (*a*) 24.0 in. (*b*) 8.05 rad/s^2 ↲.
16.78 (*a*) 107.1 rad/s^2 ↲. (*b*) $\mathbf{C}_x = 21.4$ N ←, $\mathbf{C}_y = 39.2$ N ↑.
16.79 (*a*) 150.0 mm. (*b*) 125.0 rad/s^2 ↲.
16.81 (*a*) 1529 kg. (*b*) 2.90 mm.
16.82 13.64 kN →.
16.84 (*a*) 1.500 g ↓. (*b*) 0.250 mg ↑.
16.85 (*a*) 1.286 g ↓. (*b*) 0.571 mg ↑.
16.86 (*a*) 2.50 g ↓. (*b*) 0.375 mg ↑.
16.87 150.1 N ∠ 83.2°.
16.88 (*a*) 9.66 rad/s^2 ↰. (*b*) 5.43 lb · ft ↰.
16.89 (*a*) 13.50 rad/s^2 ↰. (*b*) 6.79 N · m ↰.
16.95 2.55 ft.
16.96 $\tan\beta = \mu_s(1 + r^2/\bar{k}^2)$.
16.97 (*a*) 2.27 m or 7.46 ft. (*b*) 0.649 m or 2.13 ft.
16.98 (*a*) rolls without sliding. (*b*) 15.46 rad/s^2 ↲, 10.30 ft/s^2 →.
16.99 (*a*) rolls without sliding. (*b*) 23.2 rad/s^2 ↲, 15.46 ft/s^2 →.
16.100 (*a*) slides. (*b*) 4.29 rad/s^2 ↰, 9.66 ft/s^2 →.
16.101 (*a*) slides. (*b*) 12.88 rad/s^2 ↰. 3.22 ft/s^2 ←.
16.102 (*a*) 17.78 rad/s^2 ↰. 2.13 m/s^2 →. (*b*) 0.122.
16.105 (*a*) 8.89 rad/s^2 ↰. 1.067 m/s^2 ←. (*b*) 0.165.
16.106 (*a*) $0.556\,g$ ↓. (*b*) $1.000\,g$ ↓. (*c*) 0.
16.107 (*a*) $1.125\,g$ ↓. (*b*) $1.000\,g$ ↓. (*c*) $1.333\,g$ ↓.
16.108 (*a*) $0.765\,g$ ↓. (*b*) $1.000\,g$ ↓. (*c*) $0.667\,g$ ↓.
16.109 (*a*) 5.57 ft/s^2 ←. (*b*) 0.779 lb. ←.

16.110 (*a*) 64.4 rad/s^2 ↰. (*b*) 26.8 ft/s^2 ↓.
16.111 (*a*) 1.536 P/mr ↲. (*b*) 0.884 $P(mg + P)$.
16.113 (*a*) 0.1250 g/r ↲. 0.1250 g →, 0.1250 g ↓.
16.116 $\mathbf{P}$ = 16.84 N ∠ 70.5; $\mathbf{M}_P$ = 0.228 N · m ↲.
16.117 (*a*) 11.11 rad/s^2 ↲. (*b*) 37.7 N ↑. (*c*) 28.2 N →.
16.118 (*a*) 97.8 N ↑. (*b*) 60.3 N ↑.
16.119 (*a*) 11.15 rad/s^2 ↰. (*b*) 1.155 lb ←.
16.121 (*a*) 12.04 rad/s^2 ↲. (*b*) 1.795 lb ∠ 20°.
16.124 6.40 N ←.
16.125 171.7 N →.
16.126 60.0 N →.
16.127 33.0 lb ↑.
16.128 2.32 lb ↓.
16.129 29.9 N ∠ 60°.
16.130 23.5 N ∠ 60°.
16.133 0.330 lb ←.
16.134 (*a*) 15.00 N · m ↰. (*b*) 120.0 N →, 88.2 N ↑.
16.135 (*a*) 25.0 N · m ↰. (*b*) 190.0 N →, 104.9 N ↑.
16.136 $\mathbf{A}$ = 1.565 lb ↑, $\mathbf{B}$ = 1.689 lb ↑.
16.138 $\mathbf{B}$ = 805 N ←, $\mathbf{D}$ = 426 N →.
16.139 $\mathbf{B}$ = 525 N ∠ 38.1°, $\mathbf{D}$ = 322 N ∠ 15.7°.
16.140 $(mv_D^2/6L)\tan\theta/\cos^3\theta$.
16.141 (*a*) 9.36 m/s^2 ∠ 27.1°. (*b*) 278 N ↑.
16.142 (*a*) 9.10 m/s^2 ∠ 81.1°. (*b*) 6.54 N.
16.143 (*a*) *A*: 0.400 g/r ↰; *B*: 0.400 g/r ↲. (*b*) 0.200 mg. (*c*) 0.800 g ↓.
16.144 (*a*) 18.49 ft/s^2 ∠ 25°. (*b*) 8.38 rad/s^2 ↲.
16.146 (*a*) 13.55 m/s^2 ↓. (*b*) 2.34 m/s^2 ↓.
16.147 (*a*) 6.40 ft/s^2 →. (*b*) 45.4 rad/s^2 ↰.
16.151 10.39 lb · in. located 20.8 in. below *A*.
16.153 27.2 rad/s^2 ↰.
16.156 20.6 ft.
16.157 (*a*) 0.513 g/L ↲. (*b*) 0.912 mg ↑. (*c*) 0.241 mg →.
16.159 (1): (*a*) 1.200 g/c ↲. (*b*) 0.671 ∠ 63.4°.
(2): (*a*) 1.412 g/c ↲. (*b*) 0.706 g ↓.
(3): (*a*) 2.40 g/c ↲. (*b*) 0.500 g ↓.
16.160 (*a*) 0.333 g ↑. (*b*) 1.667 g ↓.
16.161 23.7 rad/s^2 ↰.
16.163 (*a*) 51.2 rad/s^2 ↲. (*b*) 21.0 N ↑.
16.164 (*a*) 57.8 rad/s^2 ↲. (*b*) 20.4 N ↑.

CHAPTER 17

17.1 87.8 lb · ft.
17.2 5230 rev.
17.3 0.760.
17.4 98.8 mm.
17.5 (*a*) 293 rpm. (*b*) 15.92 rev.
17.8 19.77 rev.
17.9 (*a*) 6.35 rev. (*b*) 7.14 N.
17.10 (*a*) 2.54 rev. (*b*) 17.86 N.
17.11 (*a*) 9.73 ft/s ↓. (*b*) 7.65 ft.
17.12 70.1 lb ↓.
17.13 80.7 lb ↓.
17.16 11.13 rad/s ↰.
17.17 3.27 rad/s ↲.
17.18 (*a*) 1.732$\sqrt{g/l}$ ↲, 2.50 W ↑. (*b*) 5.67 rad/s ↲, 4.50 lb ↑.
17.20 (*a*) 3.94 rad/s ↲, 271 lb ∠ 5.25°. (*b*) 5.58 rad/s ↲. 701 lb ↑.
17.24 (*a*) 3.00 m/s →. (*b*) 30.0 N ←.
17.25 1.154$\sqrt{gs}$.
17.26 $\sqrt{gs}$.
17.27 (*a*) 5.00 rad/s. (*b*) 24.9 N ↑.
17.28 0.577$\sqrt{g/r}$.
17.29 (*a*) 1.324$\sqrt{g/r}$ ↰. (*b*) 2.12 mg.
17.30 (*a*) 2.06 ft. (*b*) 4.00 lb.
17.33 0.745 m/s →.
17.34 1.000 m/s →.
17.35 1.054 m/s →.
17.36 3.11 m/s →, 1.798 m/s ↓.
17.37 4.82 m/s →, 0.
17.39 3.71 rad/s ↰, 7.74 ft/s ↑.
17.40 0.775 $\sqrt{g/l}$ ←, 0.775 $\sqrt{g/l}$ ∠ 60°.
17.42 (*a*) 0.926$\sqrt{gL}$ ←. (*b*) 1.225$\sqrt{gL}$ ←.
17.44 15.03 ft/s ↓.
17.45 84.7 rpm ↲.
17.46 110.8 rpm ↲.
17.47 0.770 m/s ←.
17.48 (*a*) 21.2 N · m. (*b*) 127.3 N · m.
17.50 (*a*) 39.8 N · m. (*b*) 95.5 N · m. (*c*) 229 N · m.
17.52 1.212 N · m.
17.53 47.4 min.
17.54 2.84 s.
17.57 5.26 s.
17.59 3.88 s.
17.60 5.22 s.
17.61 3.13 s.
17.63 $\omega_0(1 + m_A/m_B)$
17.64 (*a*) 686 rpm ↰, 514 rpm ↲. (*b*) 4.18 lb · s ↑.
17.69 (*a*) $r^2gt\sin\beta/(r^2 + \bar{k}^2)$ ∠ β. (*b*) $\bar{k}^2\tan\beta/(r^2 + \bar{k}^2)$.
17.70 2.79 ft.
17.71 (*a*) 2.55 m/s ↑. (*b*) 10.53 N.
17.72 (*a*) 27.6 ft/s ↓. (*b*) 4.00 lb.
17.74 (*a*) 2.12 m/s →. (*b*) 0.706 m/s →.
17.75 (*a*) 0.706 m/s →. (*b*) 1.235 m/s →.
17.77 (*a*) 0.286$r\omega_0/\mu_k g$. (*b*) 0.286$r\omega_0$ →, 0.286ω_0 ↲.
17.78 (*a*) 2.50$\bar{v}_0/r$. (*b*) $\bar{v}_0/\mu_k g$.
17.79 84.2 rpm.
17.81 (*a*) 2.54 rad/s. (*b*) 1.902 J.
17.82 (*a*) 5.00 rad/s. (*b*) 3.13 rad/s.
17.83 18.07 rad/s.
17.84 −24.4 rpm.
17.86 disk: 337 rpm; plate: 23.5 rpm.
17.87 37.2 rpm.
17.88 (*a*) 15.00 rad/s. (*b*) 6.14 m/s.
17.89 (*a*) 149.2 mm. (*b*) 4.44 rad/s.
17.90 1.136 m/s.
17.94 1.542 m/s.
17.95 2.01 ft/s ←.
17.96 (*a*) 25.2 rad/s ↲. (*b*) 1545 lb →.
17.97 (*a*) 10.00 in. (*b*) 22.6 rad/s ↲.
17.98 (*a*) 2.16 m/s →. (*b*) 4.87 kN ∠ 66.9°.
17.99 (*a*) 79.2 mm. (*b*) 1.992 m/s →.
17.100 242 mm/s →.
17.101 302 mm/s ←.
17.102 14.10 rad/s ↰.
17.105 $\omega_1/2$ ↲, $L\omega_1/4$ ↑.
17.106 (*a*) $3v_1/L$ ↲, $v_1/2$ ↓. (*b*) $3v_1/L$ ↰, $v_1/2$ ↑. (*c*) 0, v_1 ↑.
17.107 $\pi L/3$.
17.108 $(2 + 5\cos\beta)\omega_1/7$ ↰, $(2 + 5\cos\beta)\bar{v}_1/7$ ←.
17.110 $6v_1\sin\beta/(1 + 3\sin^2\beta)L$ ↲.
17.112 0.750 v_0/L ↲, 0.910 v_0 ∠ 74.1°.
17.113 0.706 v_0/L ↲, 0.949 v_0 ∠ 87.9°.
17.114 0.366.
17.115 8.80 ft/s.

17.116 5.12°.
17.117 55.9°.
17.120 (*a*) 2.86 in. (*b*) 2.05 in.
17.121 (*a*) 3.85 ft/s↓. (*b*) 5.13 rad/s ↓.
17.122 (*a*) 0.256 ft/s.
17.123 $0.650\sqrt{gL}$ →.
17.124 $0.866\sqrt{gL}$ →.
17.125 725 mm.
17.126 447 mm.
17.128 (*a*) 2.60 rad/s ↓. (*b*) 1.635 m/s ◹ 53.4°.
17.131 (*a*) $\mathbf{v}_A = 0$, $\boldsymbol{\omega}_A = v_1/r$ ↓; $\mathbf{v}_B = v_1$ →; $\boldsymbol{\omega}_B = 0$.
(*b*) $\mathbf{v}'_A = 2v_1/7$; $\mathbf{v}'_B = 5v_1/7$.
17.132 $1.25\, v_0/r$.
17.133 (*a*) $\mathbf{v}_A = (v_0 \sin\theta)\mathbf{j}$, $\mathbf{v}_B = (v_0 \cos\theta)\mathbf{i}$, $\boldsymbol{\omega}_A = v_0\,(-\sin\theta\,\mathbf{i} + \cos\theta\,\mathbf{j})/r$, $\boldsymbol{\omega}_B = 0$. (*b*) $\mathbf{v}'_B = (5\, v_0 \cos\theta/7)\mathbf{i}$.
17.134 $\boldsymbol{\omega}_{AB} = 2.65$ rad/s ↓, $\boldsymbol{\omega}_{BC} = 13.25$ rad/s ↰.
17.135 $\mathbf{A} = 100.1$ N ↑, $\mathbf{B} = 43.9$ N →.
17.136 (*a*) 118.7 rev. (*b*) 7.16 s.
17.138 (*a*) 53.1°. (*b*) $1.095\sqrt{gL}$ ◹ 53.1°.
17.139 7.83 N →, 7.35 N ↑.
17.141 (*a*) $1.500\, v_1/b$ ↓. (*b*) $0.791\, v_1$ ◿ 18.4°.
17.143 (*a*) 4.81 rad/s ↓. (*b*) 6.81 rad/s ↓.
17.145 $0.400\, r$
17.146 (*a*) 1.286 rad/s ↰. (*b*) 0.719 lb →, 1.006 lb ↑.

CHAPTER 18

18.1 0.357 kg · m²/s; $\theta_x = 48.6°$, $\theta_y = 41.4°$, $\theta_z = 90°$.
18.2 $0.250\, mr^2\boldsymbol{\omega}_2\,\mathbf{j} + 0.500\, mr^2\boldsymbol{\omega}_1\mathbf{k}$.
18.3 $(ma^2\boldsymbol{\omega}/12)(3\,\mathbf{j} + 2\,\mathbf{k})$.
18.4 11.88°.
18.7 (*a*) $0.276\, ma^2\boldsymbol{\omega}$. (*b*) 25.2°.
18.8 (*a*) $0.432\, ma^2\boldsymbol{\omega}$. (*b*) 20.2°.
18.9 $-(1.747$ lb · ft · s)**i** + (3.59 lb · ft · s)**j** + (0.0582 lb · ft · s)**k**.
18.10 (1.848 lb · ft · s)**i** − (0.455 lb · ft · s)**j** + (1.118 lb · ft · s)**k**.
18.11 (*a*) 2.91 rad/s. (*b*) 0.0551 rad/s.
18.12 (0.320 kg · m²/s)**i** − (0.009 kg · m²/s)**j** − (467 kg · m²/s)**k**.
18.15 (*a*) $mr^2\boldsymbol{\omega}$ (0.379 **i** − 0.483 **j**). (*b*) 51.9°.
18.16 (*a*) (0.063 kg · m²/s)**i** + (0.216 kg · m²/s)**j**.
(*b*) −(0.513 kg · m²/s)**i** + (0.216 kg · m²/s)**j**.
18.19 (*a*) −(1.041 lb · ft · s)**i** + (1.041 lb · ft · s)**j** + (2.31 lb · ft · s)**k**. (*b*) 147.5°.
18.20 (*a*) −(1.041 lb · ft · s)**i** − (1.041 lb · ft · s)**j** + (2.31 lb · ft · s)**k**. (*b*) 32.5°.
18.21 226 lb.
18.22 2.66 s.
18.23 (*a*) −(0.300 m/s)**k**. (*b*) −(0.962 rad/s)**i** − (0.577 m/s)**j**.
18.24 (*a*) (0.300 m/s)**j**.
(*b*) −(3.46 rad/s)**i** + (1.923 rad/s)**j** − (0.857 rad/s)**k**.
18.25 (*a*) $(F\Delta t/m)$**i**. (*b*) $(F\Delta t/ma)(-1.714\,\mathbf{j} + 8.57\,\mathbf{k})$.
18.26 (*a*) $(F\Delta t/m)$**i**. (*b*) $(F\Delta t/ma)(3.43\,\mathbf{j} - 5.14\,\mathbf{k})$.
18.29 (*a*) $0.125\,\boldsymbol{\omega}_0\,(-\mathbf{i} + \mathbf{j})$. (*b*) $0.0884\, a\boldsymbol{\omega}_0\,\mathbf{k}$.
18.30 (*a*) $0.1031\, ma\boldsymbol{\omega}_0\,\mathbf{k}$. (*b*) $-0.01473\, ma\boldsymbol{\omega}_0\,\mathbf{k}$.
18.31 $(0.429\,\bar{v}_0/c)\mathbf{i} + (0.429\,\bar{v}_0/a)\mathbf{k}$.
18.32 (*a*) $-(6\,\bar{v}_0/7)\mathbf{j}$. (*b*) $(m\bar{v}_0/7)\mathbf{j}$.
18.33 (*a*) *C* and *B*. (*b*) *C*: 8.16 s, *D*: 4.84 s. (*c*) 0.520 s.
18.34 (*a*) *D* and *A*. (*b*) *D*: 6.82 s, *A*: 1.848 s. (*c*) 0.347 s.
18.39 1.417 J.
18.40 $0.1250\, mr^2(\boldsymbol{\omega}_2^2 + 2\boldsymbol{\omega}_1^2)$.
18.41 $0.1250\, ma^2\boldsymbol{\omega}^2$.
18.42 $0.228\, mr^2\boldsymbol{\omega}^2$.
18.43 $0.1896\, mr^2\boldsymbol{\omega}^2$.
18.44 1.296 J.
18.47 13.34 ft · lb.
18.48 12.67 ft · lb.
18.49 $0.1250\, ma^2\boldsymbol{\omega}^2$.
18.50 $0.203\, ma^2\boldsymbol{\omega}^2$.
18.53 16.75 ft · lb.
18.54 39.9 ft · lb.
18.55 (3.21 N · m)**k**.
18.56 $0.500\, mr^2\boldsymbol{\omega}_1\boldsymbol{\omega}_2\,\mathbf{i}$.
18.57 $0.1667\, ma^2\boldsymbol{\omega}^2\,\mathbf{i}$.
18.58 $-0.958\, mr^2\boldsymbol{\omega}^2\,\mathbf{k}$.
18.59 (2.91 lb · ft)**i**.
18.61 (1.890 N · m)**i** + (2.14 N · m)**j** + (3.21 N · m)**k**.
18.62 −(1.890 N · m)**i** − (2.14 N · m)**j** + (3.21 N · m)**k**.
18.65 $\mathbf{A} = -(12.00$ N)**i**, $\mathbf{B} = -(4.00$ N)**i**.
18.66 $\mathbf{C} = \dfrac{1}{6}\, mb\boldsymbol{\omega}^2 \sin\beta\cos\beta\,\mathbf{i}$,

$\mathbf{D} = -\dfrac{1}{6}\, mb\boldsymbol{\omega}^2 \sin\beta\cos\beta\,\mathbf{i}$.

18.67 $\mathbf{A} = (3.35$ lb)**k**, $\mathbf{B} = -(3.35$ lb)**k**.
18.68 $\mathbf{A} = -(1.103$ lb)**j** − (0.920 lb)**k**,
$\mathbf{B} = (1.103$ lb)**j** + (0.920 lb)**k**.
18.71 (*a*) (20.0 rad/s²)**k**. (*b*) $\mathbf{A} = -(3.75$ N)**k**, $\mathbf{B} = -(1.250$ N)**k**.
18.72 (*a*) $(3\, M_0/mb^2 \cos^2\beta)$**j**.
(*b*) $\mathbf{C} = (M_0 \tan\beta/2b)\mathbf{k}$, $\mathbf{D} = -(M_0 \tan\beta/2b)\mathbf{k}$.
18.75 (*a*) (2.33 lb · ft)**i**.
(*b*) $\mathbf{A} = (0.466$ lb)**j**, $\mathbf{B} = -(0.466$ lb)**j**.
18.76 (*a*) (0.873 lb · ft)**i**.
(*b*) $\mathbf{A} = -(0.218$ lb)**j** + (0.262 lb)**k**,
$\mathbf{B} = (0.218$ lb)**j** − (0.262 lb)**k**.
18.77 (*a*) (0.1301 lb · ft)**i**. (*b*) $\mathbf{A} = -(0.0331$ lb)**j** + (0.0331 lb)**k**,
$\mathbf{B} = (0.0331$ lb)**j** − (0.0331 lb)**k**.
18.78 $\mathbf{A} = -(0.444$ lb)**j** − (0.383 lb)**k**,
$\mathbf{B} = (0.444$ lb)**j** + (0.383 lb)**k**.
18.79 (*a*) 10.47 N · m. (*b*) 10.47 N · m.
18.80 4.29 kN · m.
18.81 −(0.457 lb · ft)**i**.
18.83 24.0 N.
18.84 1.138° ↓. Point *A* moves *up*.
18.85 (*a*) 38.1°. (*b*) 11.78 rad/s.
18.86 13.46 rad/s
18.87 (*a*) 53.6°. (*b*) 8.79 rad/s
18.88 $\boldsymbol{\omega} = 10 \cdot 20$ rad/s.
18.89 5.45 rad/s.
18.90 2.11 N ◿ 18.7°.
18.93 (*a*) $\mathbf{C} = -(123.4$ N)**i**, $\mathbf{D} = (123.4$ N)**i**.
(*b*) $\mathbf{C} = \mathbf{D} = 0$.
18.94 91.2 rpm.
18.95 $\mathbf{A} = (0.1906$ lb)**k**, $\mathbf{B} = -(0.1906$ lb)**k**.
18.96 7.87 rad/s
18.99 (11.23 N · m) $\cos^2\theta\,\mathbf{i}$ + (11.23 N · m) $\sin\theta\cos\theta\,\mathbf{j} - (2.81$ N · m) $\sin\theta\cos\theta\,\mathbf{k}$.
18.101 $\mathbf{C} = -(89.8$ N)**i** + (52.8 N)**k**,
$\mathbf{D} = -(89.8$ N)**i** − (52.8 N)**k**.
18.102 (*a*) (0.1962 N · m)**j**. (*b*) $\mathbf{C} = -(48.6$ N)**i** + (38.9 N)**k**,
$\mathbf{D} = -(48.6$ N)**i** − (38.9 N)**k**.
18.103 (*a*) −(5.39 lb · ft)**j**. (*b*) $\mathbf{A} = -(11.65$ lb)**i** + (3.49 lb)**k**,
$\mathbf{M}_A = (5.53$ lb · ft)**i** + (8.73 lb · ft)**k**.
18.104 (*a*) (1.382 lb · ft)**i**. (*b*) $\mathbf{D} = -(6.70$ lb)**j** + (4.89 lb)**k**,
$\mathbf{E} = -(1.403$ lb)**j** + (4.89 lb)**k**.
18.107 299 rpm.
18.108 55.3°.

18.109 1666 rpm.
18.111 45.9 rpm, 533 rpm.
18.113 23.7°.
18.114 (*a*) 52.7 rad/s. (*b*) 6.44 rad/s.
18.115 (*a*) 40.0°. (*b*) 23.5°. (*c*) 85.3°.
18.116 (*a*) 56.1 rad/s. (*b*) 5.30 rad/s.
18.125 (*a*) $\theta_x = 52.5°$, $\theta_y = 37.5°$, $\theta_z = 90°$.
(*b*) 53.8 rev/h. (*c*) 6.68 rev/h.
18.126 (*a*) $\theta_x = 90°$, $\theta_y = 17.65°$, $\theta_z = 72.35°$.
(*b*) 44.8 rev/h. (*c*) 6.68 rev/h.
18.129 (*a*) 13.19°. (*b*) 1242 rpm (retrograde).
18.130 (*a*) 109.4 rpm; $\gamma_x = 90°$, $\gamma_y = 100.05°$, $\gamma_z = 10.05°$.
(*b*) $\theta_x = 90°$, $\theta_y = 113.9°$, $\theta_z = 23.9°$.
(*c*) precession: 47.1 rpm; spin: 64.6 rpm.
18.131 (*a*) 4.00 rad/s. (*b*) 5.66 rad/s.
18.132 (*a*) $\theta_0 \le \theta \le 180° - \theta_0$.
(*b*) $\dot{\theta}_{\max} = \dot{\varphi}_0 \sin\theta_0 \cos\theta_0$. (*c*) $\dot{\varphi}_{\min} = \dot{\varphi}_0 \sin^2\theta_0$.
18.133 (*a*) $30° \le \theta \le 150°$. (*b*) $\dot{\varphi}_{\min} = 2.40$ rad/s.
(*e*) $\dot{\theta}_{\max} = 3.29$ rad/s.
18.134 (*a*) $\dot{\varphi}_{\min} = 1.200$ rad/s. (*b*) $\dot{\theta}_{\max} = 2.68$ rad/s.
18.137 (*a*) 44.1°. (*b*) $\dot{\varphi} = -8.72$ rad/s, $\dot{\psi} = 56.3$ rad/s.
18.138 (*a*) 32.7 rad/s. (b) $\dot{\varphi} = -13.33$ rad/s, $\dot{\psi} = 44.3$ rad/s.
18.140 (*a*) $\frac{1}{2}I'(\dot{\varphi}\sin\theta)^2 + \frac{1}{2}I'\dot{\theta}^2 + \frac{1}{2}I\omega_z^2 + mge\cos\theta = E$.
18.147 $(0.234 \text{ kg} \cdot \text{m}^2/\text{s})\mathbf{j} + (1.250 \text{ kg} \cdot \text{m}^2/\text{s})\mathbf{k}$.
18.148 (*a*) $-(1.098 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{i} + (1.098 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{j} + (2.74 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{k}$.
(*b*) 150.5°.
18.150 (*a*) $-\frac{1}{6}\omega_0\mathbf{i} + \frac{1}{6}\omega_0\mathbf{j}$. (*b*) $\frac{1}{6}\omega_0 a\mathbf{k}$.
18.151 $\frac{5}{48}ma^2\omega_0^2$.
18.153 (*a*) 52.1 rad/s^2. (*b*) $\mathbf{A} = -(2.50 \text{ N})\mathbf{i}$, $\mathbf{B} = (2.50 \text{ N})\mathbf{i}$.
18.154 (*a*) 53.4°. (*b*) 9.27 rad/s.
18.155 (*a*) $(2.71 \text{ lb} \cdot \text{ft})\mathbf{j}$. (*b*) $\mathbf{F} = -(5.30 \text{ lb})\mathbf{i} - (1.988 \text{ lb})\mathbf{k}$;
$\mathbf{M}_0 = (2.69 \text{ lb} \cdot \text{ft})\mathbf{i} - (4.42 \text{ lb} \cdot \text{ft})\mathbf{k}$.
18.156 (*a*) $\mathbf{A} = (1.786 \text{ kN})\mathbf{i} + (143.5 \text{ kN})\mathbf{j}$;
$\mathbf{B} = -(1.786 \text{ kN})\mathbf{i} + (150.8 \text{ kN})\mathbf{j}$. (*b*) $-(35.7 \text{ kN} \cdot \text{m})\mathbf{k}$.
18.157 1326 rpm.

CHAPTER 19

19.1 1.047 ft/s, 65.8 ft/s^2.
19.2 0.950 mm, 239 mm/s.
19.3 1.225 m/s, 0.650 Hz.
19.4 (*a*) 0.391 s, 2.55 Hz. (*b*) 2.81 ft/s, 45.1 ft/s^2.
19.5 (*a*) 0.324 s, 3.08 Hz. (*b*) 12.91 mm, 484 m/s^2.
19.6 (*a*) 10.75°. (*b*) 6.04 ft/s^2.
19.7 (*a*) 0.557 Hz. (*b*) 293 mm/s.
19.9 (*a*) 3.14 s. (*b*) 6.40 m. (*c*) 38.7°.
19.11 (*a*) 5.49 m. (*b*) 80.5 m/s^2 ↓.
19.12 (*a*) 0.0352 s. (*b*) 6.34 ft/s ↑, 64.9 ft/s^2 ↓.
19.13 0.445 ft ↑, 2.27 ft/s ↓, 114.7 ft/s^2 ↓.
19.14 (*a*) 3.89°. (*b*) 0.1538 m/s, 0.666 m/s^2.
19.17 (*a*) 0.208 s, 4.81 Hz. (*b*) 1.361 m/s, 41.1 m/s^2.
19.18 (*a*) 0.416 s, 2.41 Hz. (*b*) 0.680 m/s, 10.29 m/s^2.
19.19 (*a*) 0.361 s, 2.77 Hz. (*b*) 2.54 ft/s, 441 ft/s^2.
19.20 2.63 s.
19.23 (*a*) 6.82 lb. (*b*) 33.4 lb/ft.
19.24 (*a*) 6.80 kg. (*b*) 0.583 s.
19.25 (*a*) 35.6 lb/in. (*b*) 5.01 lb.
19.26 192.0 lb/ft.
19.27 (*a*) 22.3 MN/m. (*b*) 266 Hz.
19.30 (*a*) 55.4 mm. (*b*) 1.497 Hz.
19.34 16.3°
19.35 (*a*) 1.737 s. (*b*) 1.864 s. (*c*) 2.05 s.
19.36 28.1 in.
19.37 (*a*) 3.36 Hz. (*b*) 42.6 mm.
19.38 (*a*) 0.315 s. (*b*) 0.665 ft/s.
19.39 (*a*) 0.1957 s. (*b*) 171.7 ft/s^2.
19.40 (*a*) 0.491 s. (*b*) 9.60 in./s.
19.43 (*a*) 1.117 rad/s. (*b*) 400 mm.
19.44 (*a*) 2.28 s. (*b*) 1.294 m.
19.45 75.5°.
19.46 0.379 Hz.
19.47 (*a*) 1.067 s. (*b*) 89.7 mm.
19.49 (*a*) 0.933 s. (*b*) 0.835 s.
19.50 (*a*) 1.617 s. (*b*) 1.676 s.
19.55 (*a*) 2.21 Hz. (*b*) 115.3 N/m.
19.56 3.03 Hz.
19.57 0.945 Hz.
19.58 $0.276\sqrt{k/m - g/4L}$.
19.59 (*a*) 88.1 mm/s. (*b*) 85.1 mm/s.
19.61 82.1 mm/s.
19.63 (*a*) 21.3 kg. (*b*) 1.838 s.
19.64 (*a*) 0.826 s. (*b*) 1.048 s.
19.65 (*a*) 1.951 s. (*b*) 1.752 m/s.
19.66 4.86 lb · ft · s^2.
19.69 $2\pi\sqrt{l/g}$.
19.70 3.18 s.
19.71 1.476 m/s, 31.1 m/s^2.
19.72 1.379 in., 888 in./s^2.
19.73 0.289 l.
19.76 130.6 mm.
19.77 $0.276\sqrt{k/m - g/4L}$.
19.78 (*a*) 0.715 s. (*b*) 0.293 ft/s.
19.79 2.10 Hz.
19.80 0.387 s.
19.83 1.834 s.
19.84 $0.1899\sqrt{g/l}$.
19.85 1.327 s.
19.88 2.39 s.
19.89 $2\pi\sqrt{2m/3k}$.
19.90 0.911 Hz.
19.91 (*a*) $0.1592\sqrt{(g/l)(ka^2/\omega l - 1)}$. (*b*) $\sqrt{\omega l/k}$.
19.92 6.64 lb.
19.94 0.742 Hz.
19.96 $(2\pi/\cos\beta)\sqrt{m/6k}$.
19.97 (*a*) 0.352 s. (*b*) 0.352 s.
19.98 $1.814\, l/\sqrt{gr}$.
19.99 11.40 N.
19.100 (*a*) 0.1304 ft (in phase). (*b*) 1.464 ft (out of phase).
19.101 (*a*) 10.99 lb/ft. (*b*) 2.99 lb/ft.
19.102 $\sqrt{k/2m} < \omega_f < \sqrt{3k/2m}$.
19.105 $\omega_f < 8.16$ rad/s.
19.106 22.5 mm, 5.63 mm.
19.107 $\omega_f < 9.83$ rad/s. and $\omega_f > 17.02$ rad/s.
19.108 651 rpm.
19.109 (*a*) 90.0 mm. (*b*) 18.00 N.
19.112 (*a*) 25.2 mm. (*b*) $-0.437\sin(\pi t)$ N.
19.113 Show . . .
19.114 22.0 mm.
19.115 $\omega_f \le 322$ rpm and $\omega_f \ge 329$ rpm.
19.116 783 rpm.
19.118 39.1 kg

19.120 $\omega_f \leq 254$ rpm and $\omega_f \geq 303$ rpm.
19.121 (*a*) 4.17%. (*b*) 84.9 Hz.
19.122 8.04%.
19.123 (1) $|1/(1 - \omega_f^2/\omega_n^2)|$; (2) $|1/(1 - \omega_f^2/\omega_n^2)|$.
19.124 (*a*) 1399 rpm. (*b*) 0.01669 in.
19.132 (*a*) 0.01393. (*b*) 0.0417 lb · s/ft.
19.133 (*a*) 6.49 kip · s/ft. (*b*) 230 kips/ft.
19.134 56.9 mm.
19.136 (*a*) 6490 lb/ft. (*b*) 0.1939 s.
19.137 (*a*) $\ddot{\theta} + (3\,c/m)\,\dot{\theta} + (3k/4m)\,\theta = 0$. (*b*) $\sqrt{km/3}$.
19.139 0.0725 in.
19.141 $c/c_c \geq 0.707$.
19.143 (*a*) 0.0905. (*b*) 366 N · s/m.
19.144 (*a*) −0.324 mm. (*b*) 0.0884 mm.
19.145 13.01 mm.
19.146 (*a*) 2210 kN/m. (*b*) 0.0286.
19.147 134.8 mm, 143.7 N.
19.149 (*a*) 16.18 lb. (*b*) 8.18 lb.
19.151 (*a*) $m\dfrac{d^2x}{dt^2} + c\dfrac{dx}{dt} + kx = \delta_m(k \sin \omega_f t + c\omega_f \cos \omega_f t)$
where $\omega_f = 2\pi v/L$.
(*b*) $\delta_m\sqrt{k^2 + (c\omega_f)^2}/\sqrt{(k - m\omega_f^2)^2 + (c\omega_f)^2}$.
19.153 $R < 2\sqrt{LC}$.
19.154 (*a*) E/R (*b*) L/R
19.155 Draw . . .
19.156 Draw . . .
19.157 (*a*) $kx_A + c\dfrac{d}{dt}(x_A - x_m) = 0$,

$$m\frac{d^2x_m}{dt^2} + c\frac{d}{dt}(x_m - x_A) = P_m \sin \omega_f t.$$

(*b*) $\dfrac{1}{C}q_A + R\dfrac{d}{dt}(q_A - q_m) = 0$,

$$L\frac{d^2q_m}{dt^2} + R\frac{d}{dt}(q_m - q_A) = E_m \sin \omega_f t.$$

19.158 (*a*) $m\dfrac{d^2x_m}{dt^2} + k_2(x_m - x_A) = P_m \sin \omega_f t.$

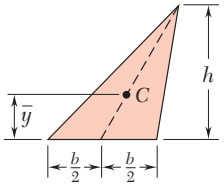
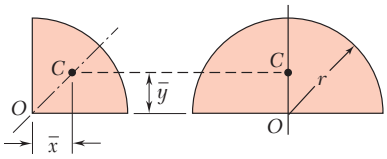
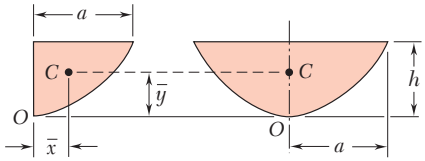
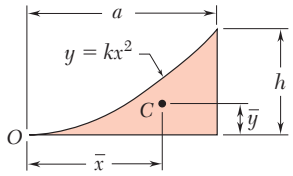
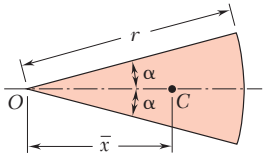
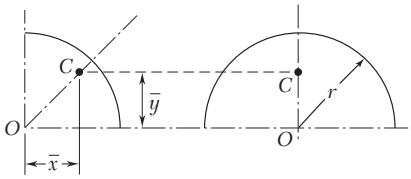
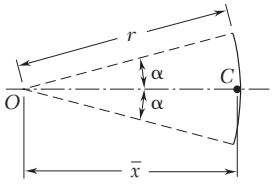
$$C\frac{dx_A}{dt} + k_1x_A + k_2(x_A + x_m) = 0$$

(*b*) $L\dfrac{d^2q_m}{dt^2} + \dfrac{1}{C_2}(q_m - q_A) = E_m \sin \omega_f t$

$$R\frac{dq_A}{dt} + \frac{1}{C_1}q_A + \frac{1}{C_2}(q_A - q_m) = 0$$

19.159 (*a*) $2\pi\sqrt{2a/3g}$. (*b*) 0.1667 *a*.
19.161 1.785 s.
19.163 (*a*) 6.16 Hz, 4.91 mm, 0.1900 m/s. (*b*) 4.91 N, (*c*) 0.1542 m/s ↓.
19.164 (*a*) 0.316 L. (*b*) $0.200\sqrt{g/L}$
19.166 1.456 m.
19.169 (*a*) 5.75 N. (*b*) 0.00710 mm.
19.170 (*a*) $m\ddot{x} + 4Tx/l = 0$ (*b*) $\pi\sqrt{ml/T}$.

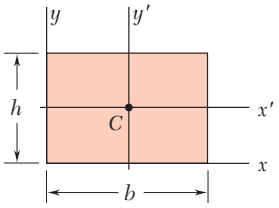
Centroids of Common Shapes of Areas and Lines

Shape		$\bar{x}$	$\bar{y}$	Area
Triangular area			$\frac{h}{3}$	$\frac{bh}{2}$
Quarter-circular area		$\frac{4r}{3\pi}$	$\frac{4r}{3\pi}$	$\frac{\pi r^2}{4}$
Semicircular area		0	$\frac{4r}{3\pi}$	$\frac{\pi r^2}{2}$
Semiparabolic area		$\frac{3a}{8}$	$\frac{3h}{5}$	$\frac{2ah}{3}$
Parabolic area		0	$\frac{3h}{5}$	$\frac{4ah}{3}$
Parabolic spandrel		$\frac{3a}{4}$	$\frac{3h}{10}$	$\frac{ah}{3}$
Circular sector		$\frac{2r\sin\alpha}{3\alpha}$	0	αr^2
Quarter-circular arc		$\frac{2r}{\pi}$	$\frac{2r}{\pi}$	$\frac{\pi r}{2}$
Semicircular arc		0	$\frac{2r}{\pi}$	πr
Arc of circle		$\frac{r\sin\alpha}{\alpha}$	0	$2\alpha r$

Moments of Inertia of Common Geometric Shapes

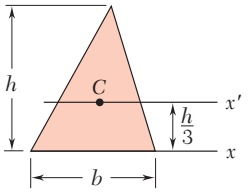
Rectangle

$$\bar{I}_{x'} = \tfrac{1}{12}bh^3$$
$$\bar{I}_{y'} = \tfrac{1}{12}b^3h$$
$$I_x = \tfrac{1}{3}bh^3$$
$$I_y = \tfrac{1}{3}b^3h$$
$$J_C = \tfrac{1}{12}bh(b^2 + h^2)$$



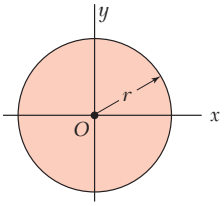
Triangle

$$\bar{I}_{x'} = \tfrac{1}{36}bh^3$$
$$I_x = \tfrac{1}{12}bh^3$$



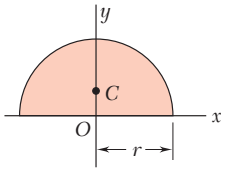
Circle

$$\bar{I}_x = \bar{I}_y = \tfrac{1}{4}\pi r^4$$
$$J_O = \tfrac{1}{2}\pi r^4$$



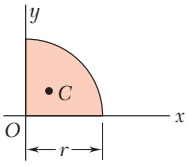
Semicircle

$$I_x = I_y = \tfrac{1}{8}\pi r^4$$
$$J_O = \tfrac{1}{4}\pi r^4$$



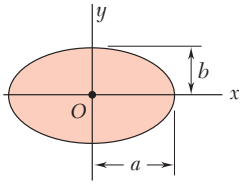
Quarter circle

$$I_x = I_y = \tfrac{1}{16}\pi r^4$$
$$J_O = \tfrac{1}{8}\pi r^4$$



Ellipse

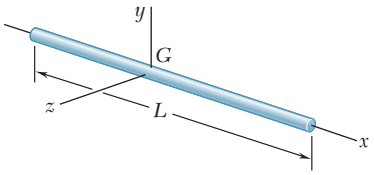
$$\bar{I}_x = \tfrac{1}{4}\pi ab^3$$
$$\bar{I}_y = \tfrac{1}{4}\pi a^3b$$
$$J_O = \tfrac{1}{4}\pi ab(a^2 + b^2)$$



Mass Moments of Inertia of Common Geometric Shapes

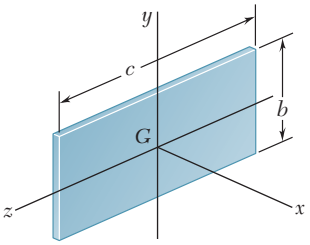
Slender rod

$$I_y = I_z = \tfrac{1}{12}mL^2$$



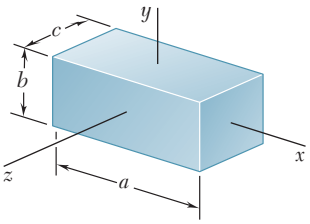
Thin rectangular plate

$$I_x = \tfrac{1}{12}m(b^2 + c^2)$$
$$I_y = \tfrac{1}{12}mc^2$$
$$I_z = \tfrac{1}{12}mb^2$$



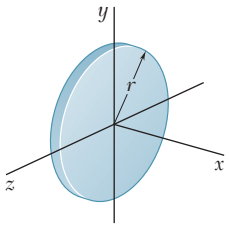
Rectangular prism

$$I_x = \tfrac{1}{12}m(b^2 + c^2)$$
$$I_y = \tfrac{1}{12}m(c^2 + a^2)$$
$$I_z = \tfrac{1}{12}m(a^2 + b^2)$$



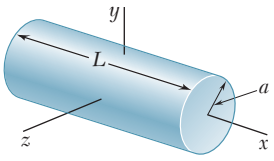
Thin disk

$$I_x = \tfrac{1}{2}mr^2$$
$$I_y = I_z = \tfrac{1}{4}mr^2$$



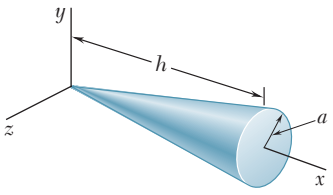
Circular cylinder

$$I_x = \tfrac{1}{2}ma^2$$
$$I_y = I_z = \tfrac{1}{12}m(3a^2 + L^2)$$



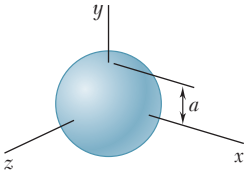
Circular cone

$$I_x = \tfrac{3}{10}ma^2$$
$$I_y = I_z = \tfrac{3}{5}m(\tfrac{1}{4}a^2 + h^2)$$

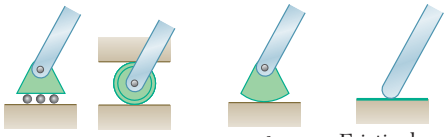
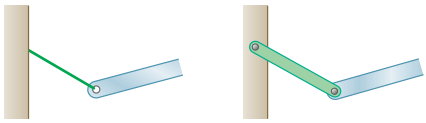
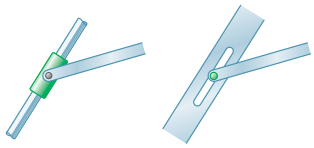
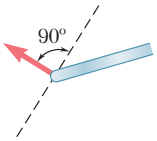
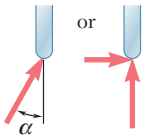
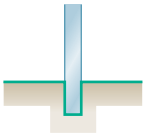
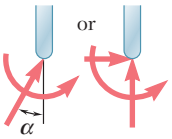


Sphere

$$I_x = I_y = I_z = \tfrac{2}{5}ma^2$$

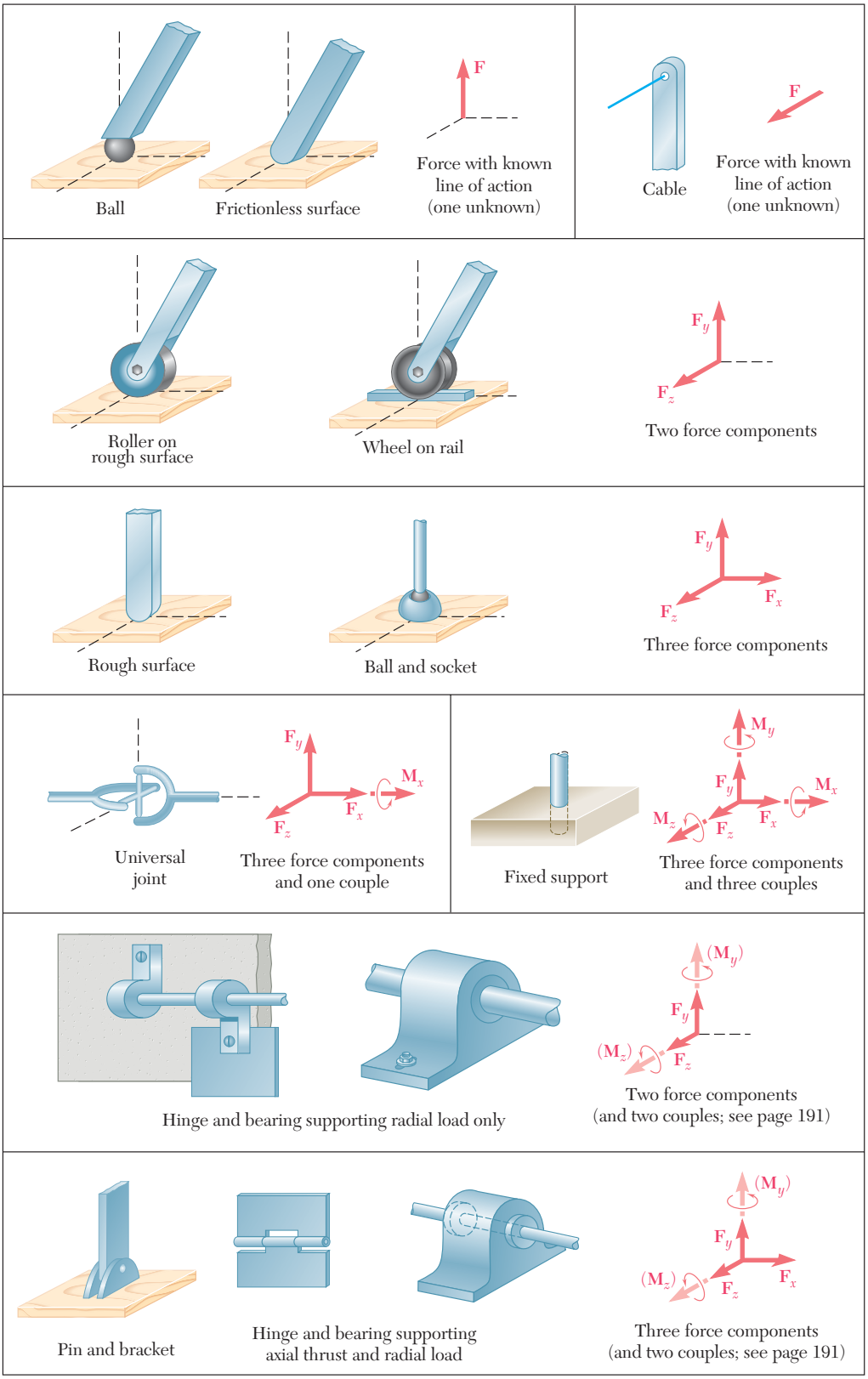


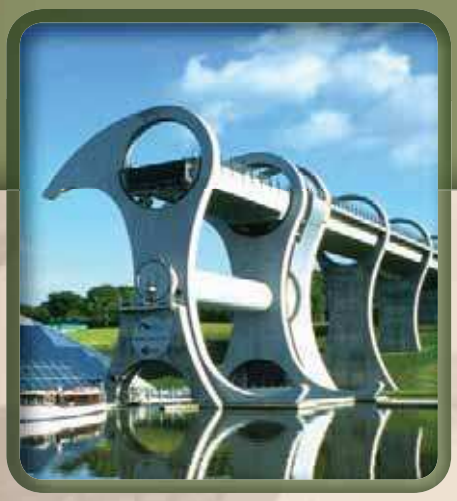
Reactions at Supports and Connections for a Two-Dimensional Structure

Support or Connection	Reaction	Number of Unknowns
 Rollers, Rocker, Frictionless surface	 Force with known line of action	1
 Short cable, Short link	 Force with known line of action	1
 Collar on frictionless rod, Frictionless pin in slot	 Force with known line of action	1
 Frictionless pin or hinge, Rough surface	 Force of unknown direction	2
 Fixed support	 Force and couple	3

e irs s e in e solu ion o an roblem on erning e e uilibrium o a rigid bod is o ons ru an a ro ria e ree-bod diagram o e bod . s ar o a ro ess i is ne essar o s ow on e diagram e rea ions roug w i e ground and o er bodies o ose a ossible mo ion o e bod . e igures on is and e a ing age summari e e ossible rea ions e er ed on wo- and ree-dimensional bodies.

Reactions at Supports and Connections for a Three-Dimensional Structure





The McGraw-Hill Companies

Mc Graw Hill Higher Education

ISBN 978-0-07-352940-0
MHID 0-07-352940-0
Part of
ISBN 978-0-07-727555-6
MHID 0-07-727555-1

EAN 9 780077 275556 90000

www.mhhe.com