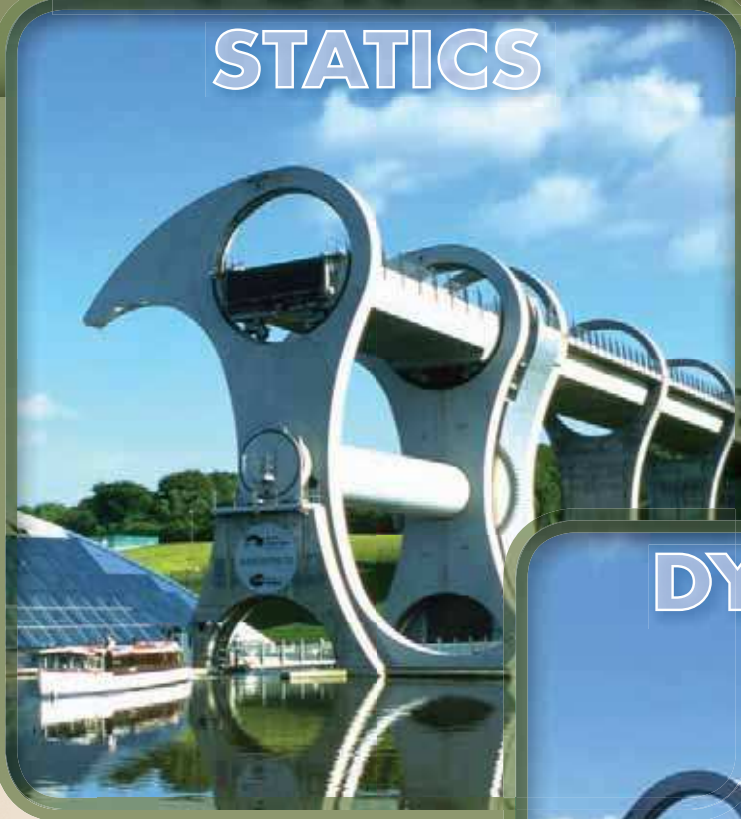
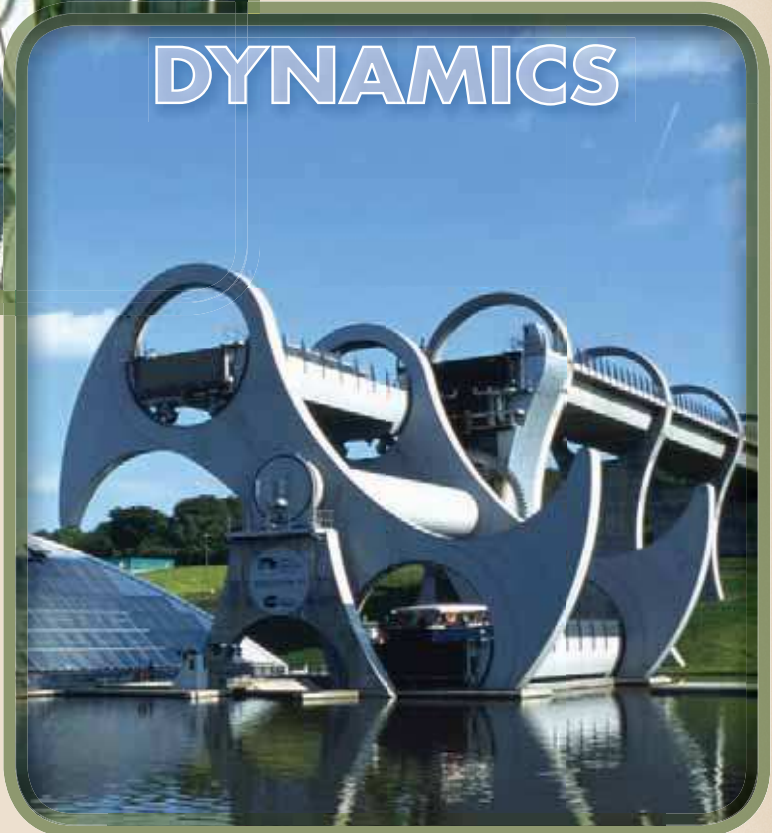


# VECTOR MECHANICS FOR ENGINEERS

STATICS



DYNAMICS



**BEER | JOHNSTON | MAZUREK | CORNWELL | EISENBERG**

Ninth Edition

NINTH EDITION

# VECTOR MECHANICS FOR ENGINEERS

## Statics and Dynamics

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## VECTOR MECHANICS FOR ENGINEERS: STATICS & DYNAMICS, NINTH EDITION

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# List of Symbols

$a$	Constant; radius; distance
$\mathbf{A}, \mathbf{B}, \mathbf{C}, \dots$	Reactions at supports and connections
$A, B, C, \dots$	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
$I, I_x, \dots$	Moments of inertia
$\bar{I}$	Centroidal moment of inertia
$I_{xy}, \dots$	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
$\alpha, \beta, \gamma$	Angles
$\gamma$	Specific weight
$\delta$	Elongation
$\delta\mathbf{r}$	Virtual displacement
$\delta U$	Virtual work
$\boldsymbol{\lambda}$	Unit vector along a line
$\eta$	Efficiency
$\theta$	Angular coordinate; angle; polar coordinate
$\mu$	Coefficient of friction
$\rho$	Density
$\phi$	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)

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

- 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  $\uparrow$ .  
**3.2** 1.277 N · m  $\uparrow$ .  
**3.3** (a) 41.7 N · m  $\uparrow$ . (b) 147.4 N  $\nearrow$  45.0°.  
**3.4** (a) 41.7 N · m  $\uparrow$ . (b) 176.8 N  $\nearrow$  58.0°.  
**3.5** 186.6 lb · in.  $\downarrow$ .  
**3.7** 6.12° or 33.8°.  
**3.9** (a) 760 N · m  $\uparrow$ . (b) 760 N · m  $\uparrow$ .  
**3.10** 1224 N.  
**3.12** 116.2 lb · ft  $\uparrow$ .  
**3.13** 128.2 lb · ft  $\uparrow$ .  
**3.16** 2.21 m.  
**3.17** (a) 41.0. (b) 26.9.  
**3.19** (a) -11i + 22j + 22k. (b) 0. (c) -45i + 30j - 10k.  
**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**  $M_x = -31.2 \text{ N} \cdot \text{m}$ ;  $M_y = 13.20 \text{ N} \cdot \text{m}$ ;  $M_z = -2.42 \text{ N} \cdot \text{m}$ .  
**3.48**  $M_x = -25.6 \text{ N} \cdot \text{m}$ ;  $M_y = 10.80 \text{ N} \cdot \text{m}$ ;  $M_z = 40.6 \text{ N} \cdot \text{m}$ .  
**3.49** 1.252 m.  
**3.50** 1.256 m.  
**3.51** 61.5 lb.  
**3.53**  $\phi = 24.6^\circ$ ;  $d = 34.6 \text{ in}$ .  
**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  $\downarrow$ . (b) 12.39 N · m  $\downarrow$ . (c) 12.39 N · m  $\downarrow$ .  
**3.71** (a) 336 lb · in.  $\uparrow$ . (b) 28.0 in. (c) 54.0°.  
**3.72** (a) 75.0 N. (b) 71.2 N. (c) 45.0 N.  
**3.75**  $M = 10.00 \text{ lb} \cdot \text{ft}$ ;  $\theta_x = 90.0^\circ$ ,  $\theta_y = 143.1^\circ$ ,  $\theta_z = 126.9^\circ$ .  
**3.76**  $M = 9.21 \text{ N} \cdot \text{m}$ ;  $\theta_x = 77.9^\circ$ ,  $\theta_y = 12.05^\circ$ ,  $\theta_z = 90.0^\circ$ .  
**3.77**  $M = 604 \text{ lb} \cdot \text{in.}$ ;  $\theta_x = 72.8^\circ$ ,  $\theta_y = 27.3^\circ$ ,  $\theta_z = 110.5^\circ$ .  
**3.78**  $M = 1170 \text{ lb} \cdot \text{in.}$ ;  $\theta_x = 81.2^\circ$ ,  $\theta_y = 13.70^\circ$ ,  $\theta_z = 100.4^\circ$ .  
**3.79**  $M = 10.92 \text{ N} \cdot \text{m}$ ;  $\theta_x = 97.8^\circ$ ,  $\theta_y = 34.5^\circ$ ,  $\theta_z = 56.7^\circ$ .  
**3.80**  $M = 2860 \text{ N} \cdot \text{m}$ ;  $\theta_x = 113.0^\circ$ ,  $\theta_y = 92.7^\circ$ ,  $\theta_z = 23.2^\circ$ .  
**3.81** (a)  $\mathbf{F} = 560 \text{ lb} \swarrow 20.0^\circ$ ;  $\mathbf{M} = 7720 \text{ lb} \cdot \text{ft} \downarrow$ .  
(b)  $\mathbf{F} = 560 \text{ lb} \swarrow 20.0^\circ$ ;  $\mathbf{M} = 4290 \text{ lb} \cdot \text{ft} \downarrow$ .  
**3.82** (a)  $\mathbf{F} = 160.0 \text{ lb} \nearrow 60.0^\circ$ ;  $\mathbf{M} = 334 \text{ lb} \cdot \text{ft} \uparrow$ .  
(b)  $\mathbf{F}_B = 20.0 \text{ lb} \uparrow$ ;  $\mathbf{F}_D = 143.0 \text{ lb} \nearrow 56.0^\circ$ .  
**3.83** (a)  $\mathbf{F}_B = 80.0 \text{ N} \leftarrow$ ;  $\mathbf{M}_B = 4.00 \text{ N} \cdot \text{m} \uparrow$ .  
(b)  $\mathbf{F}_C = 100.0 \text{ N} \downarrow$ ;  $\mathbf{F}_D = 100.0 \text{ N} \uparrow$ .  
**3.85** (a)  $\mathbf{F}_B = 250 \text{ N} \swarrow 60.0^\circ$ ;  $\mathbf{M}_B = 75.0 \text{ N} \cdot \text{m} \downarrow$ .  
(b)  $\mathbf{F}_A = 375 \text{ N} \searrow 60.0^\circ$ ;  $\mathbf{F}_B = 625 \text{ N} \swarrow 60.0^\circ$ .  
**3.87** (a)  $\mathbf{F} = -(600 \text{ N})\mathbf{k}$ ;  $d = 90.0 \text{ mm}$  below ED.  
(b)  $\mathbf{F} = -(600 \text{ N})\mathbf{k}$ ;  $d = 90.0 \text{ mm}$  above ED.  
**3.88**  $\mathbf{F} = 900 \text{ N} \downarrow$ ;  $x = 50.0 \text{ mm}$ .  
**3.89**  $(0.227 \text{ lb})\mathbf{i} + (0.1057 \text{ lb})\mathbf{k}$ ; 63.6 in. to the right of B.  
**3.90** (a)  $\mathbf{F} = 48.0 \text{ lb} \nearrow 65.0^\circ$ ;  $\mathbf{M} = 490 \text{ lb} \cdot \text{in.} \downarrow$ .  
(b)  $\mathbf{F} = 48.0 \text{ lb} \nearrow 65.0^\circ$ ; 17.78 in. to the left of B.  
**3.93**  $\mathbf{F} = -(1220 \text{ N})\mathbf{i}$ ;  $\mathbf{M} = (73.2 \text{ N} \cdot \text{m})\mathbf{j} - (122.0 \text{ N} \cdot \text{m})\mathbf{k}$ .  
**3.94**  $\mathbf{F}_C = (5.00 \text{ N})\mathbf{i} + (150.0 \text{ N})\mathbf{j} - (90.0 \text{ N})\mathbf{k}$ ;  
 $\mathbf{M}_C = (77.4 \text{ N} \cdot \text{m})\mathbf{i} + (61.5 \text{ N} \cdot \text{m})\mathbf{j} + (106.8 \text{ N} \cdot \text{m})\mathbf{k}$ .  
**3.95**  $\mathbf{F} = -(128.0 \text{ lb})\mathbf{i} - (256 \text{ lb})\mathbf{j} + (32.0 \text{ lb})\mathbf{k}$ ;  
 $\mathbf{M} = (4.10 \text{ kip} \cdot \text{ft})\mathbf{i} + (16.38 \text{ kip} \cdot \text{ft})\mathbf{k}$ .  
**3.97**  $\mathbf{F} = -(122.9 \text{ N})\mathbf{j} - (86.0 \text{ N})\mathbf{k}$ ;  
 $\mathbf{M} = (22.6 \text{ N} \cdot \text{m})\mathbf{i} + (15.49 \text{ N} \cdot \text{m})\mathbf{j} - (22.1 \text{ N} \cdot \text{m})\mathbf{k}$ .  
**3.98** (a) 135.0 mm. (b)  $\mathbf{F}_2 = (42.0 \text{ N})\mathbf{i} + (42.0 \text{ N})\mathbf{j} - (49.0 \text{ N})\mathbf{k}$ ;  
 $\mathbf{M}_2 = -(25.9 \text{ N} \cdot \text{m})\mathbf{i} + (21.2 \text{ N} \cdot \text{m})\mathbf{j}$ .  
**3.99**  $\mathbf{F} = (36.0 \text{ lb})\mathbf{i} - (28.0 \text{ lb})\mathbf{j} - (6.00 \text{ lb})\mathbf{k}$ ;  
 $\mathbf{M} = -(157.0 \text{ lb} \cdot \text{ft})\mathbf{i} + (22.5 \text{ lb} \cdot \text{ft})\mathbf{j} - (240 \text{ lb} \cdot \text{ft})\mathbf{k}$ .  
**3.101** (a) Loading a:  $\mathbf{R} = 600 \text{ N} \downarrow$ ;  $\mathbf{M} = 1000 \text{ N} \cdot \text{m} \uparrow$ .  
Loading b:  $\mathbf{R} = 600 \text{ N} \downarrow$ ;  $\mathbf{M} = 900 \text{ N} \cdot \text{m} \downarrow$ .  
Loading c:  $\mathbf{R} = 600 \text{ N} \downarrow$ ;  $\mathbf{M} = 900 \text{ N} \cdot \text{m} \uparrow$ .  
Loading d:  $\mathbf{R} = 400 \text{ N} \uparrow$ ;  $\mathbf{M} = 900 \text{ N} \cdot \text{m} \uparrow$ .  
Loading e:  $\mathbf{R} = 600 \text{ N} \downarrow$ ;  $\mathbf{M} = 200 \text{ N} \cdot \text{m} \downarrow$ .  
Loading f:  $\mathbf{R} = 600 \text{ N} \downarrow$ ;  $\mathbf{M} = 800 \text{ N} \cdot \text{m} \uparrow$ .  
Loading g:  $\mathbf{R} = 1000 \text{ N} \downarrow$ ;  $\mathbf{M} = 1000 \text{ N} \cdot \text{m} \uparrow$ .  
Loading h:  $\mathbf{R} = 600 \text{ N} \downarrow$ ;  $\mathbf{M} = 900 \text{ N} \cdot \text{m} \uparrow$ .  
(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**  $\mathbf{R} = 72.4 \text{ lb} \swarrow 81.9^\circ$ ;  $\mathbf{M} = 206 \text{ lb} \cdot \text{ft}$ .  
**3.109** (a) 34.0 lb  $\searrow 28.0^\circ$ . (b) AB: 11.64 in. to the left of B;  
BC: 6.20 in. below B.  
**3.110** (a) 48.2 lb · in.  $\uparrow$ . (b) 240 lb · in.  $\uparrow$ . (c) 0.  
**3.111** (a) 1562 N  $\searrow 50.2^\circ$ . (b) 250 mm to the right of C and  
300 mm above C.  
**3.112** (a) 1308 N  $\nearrow 66.6^\circ$ . (b) 412 mm to the right of A and  
250 mm to the right of C.  
**3.113** 773 lb  $\nearrow 79.0^\circ$ ; 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)  $\mathbf{R} = F \searrow \tan^{-1}(a^2/2bx)$ ;  
 $\mathbf{M} = 2Fb^2(x - x^3/a^2)/\sqrt{a^4 + 4b^2x^3} \uparrow$ . (b) 0.369 m.  
**3.119**  $\mathbf{R} = -(420 \text{ N})\mathbf{i} - (50.0 \text{ N})\mathbf{j} - (250 \text{ N})\mathbf{k}$ ;  
 $\mathbf{M} = (30.8 \text{ N} \cdot \text{m})\mathbf{j} - (22.0 \text{ N} \cdot \text{m})\mathbf{k}$ .  
**3.120**  $\mathbf{R} = -(420 \text{ N})\mathbf{j} - (339 \text{ N})\mathbf{k}$ ;  
 $\mathbf{M} = (1.125 \text{ N} \cdot \text{m})\mathbf{i} + (163.9 \text{ N} \cdot \text{m})\mathbf{j} - (109.9 \text{ N} \cdot \text{m})\mathbf{k}$ .  
**3.121** (a)  $\mathbf{B} = (2.50 \text{ lb})\mathbf{i}$ ;  
 $\mathbf{C} = (0.1000 \text{ lb})\mathbf{i} - (2.47 \text{ lb})\mathbf{j} - (0.700 \text{ lb})\mathbf{k}$ .  
(b)  $R_y = -2.47 \text{ lb}$ ;  $M_x = 1.360 \text{ lb} \cdot \text{ft}$ .  
**3.122**  $\mathbf{A} = (1.600 \text{ lb})\mathbf{i} - (36.0 \text{ lb})\mathbf{j} + (2.00 \text{ lb})\mathbf{k}$ ;  
 $\mathbf{B} = -(9.60 \text{ lb})\mathbf{i} + (36.0 \text{ lb})\mathbf{j} + (2.00 \text{ lb})\mathbf{k}$ .

- 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**  $a = 0.722 \text{ ft}$ ;  $b = 20.6 \text{ ft}$ .
- 3.133** (a)  $P\sqrt{3}$ ;  $\theta_x = \theta_y = \theta_z = 54.7^\circ$ . (b)  $-a$ . (c) Axis of the wrench is diagonal  $OA$ .
- 3.134** (a)  $P$ ;  $\theta_x = 90.0^\circ$ ,  $\theta_y = 90.0^\circ$ ,  $\theta_z = 0$ . (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  $x = 0$ ,  $z = 1.667 \text{ in}$ .
- 3.137** (a)  $-(84.0 \text{ N})\mathbf{j} - (80.0 \text{ N})\mathbf{k}$ . (b) 0.477 m.  
 (c)  $x = 0.526 \text{ m}$ ,  $z = -0.1857 \text{ m}$ .
- 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**  $\mathbf{R} = (20.0 \text{ N})\mathbf{i} + (30.0 \text{ N})\mathbf{j} - (10.00 \text{ N})\mathbf{k}$ ;  
 $y = -0.540 \text{ m}$ ,  $z = -0.420 \text{ m}$ .
- 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)  $196.2 \text{ N} \cdot \text{m} \downarrow$ . (b)  $199.0 \text{ N} \searrow 59.5^\circ$ .
- 3.148**  $42.0 \text{ N} \cdot \text{m} \uparrow$ .
- 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)  $151.2 \text{ lb} \cdot \text{in} \cdot \uparrow$ . (b)  $67.2 \text{ lb} \cdot \text{in} \cdot \uparrow$ .
- 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)  $665 \text{ lb} \searrow 79.6^\circ$ ; 64.9 in. to the right of  $A$ . (b)  $22.9^\circ$ .
- 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)  $R_y = 0$ ;  $R_z = -40.0 \text{ N}$ . (c) When the slot is vertical.
- 3.C3** 4 sides:  $\beta = 10^\circ$ ,  $\alpha = 44.1^\circ$ ;  
 $\beta = 20^\circ$ ,  $\alpha = 41.6^\circ$ ;  
 $\beta = 30^\circ$ ,  $\alpha = 37.8^\circ$ .
- 3.C4**  $\theta = 0 \text{ rev}$ :  $M = 97.0 \text{ N} \cdot \text{m}$ ;  
 $\theta = 6 \text{ rev}$ :  $M = 63.3 \text{ N} \cdot \text{m}$ ;  
 $\theta = 12 \text{ rev}$ :  $M = 9.17 \text{ N} \cdot \text{m}$ .
- 3.C6**  $d_{AB} = 36.0 \text{ in}$ .;  $d_{CD} = 9.00 \text{ in}$ .;  $d_{\min} = 58.3 \text{ in}$ .
- 4.24** (a)  $\mathbf{A} = 20.0 \text{ lb} \uparrow$ ;  $\mathbf{B} = 50.0 \text{ lb} \searrow 36.9^\circ$ .  
 (b)  $\mathbf{A} = 23.1 \text{ lb} \searrow 60.0^\circ$ ;  $\mathbf{B} = 59.6 \text{ lb} \searrow 30.2^\circ$ .
- 4.26** (a) 190.9 N. (b)  $142.3 \text{ N} \searrow 18.43^\circ$ .
- 4.27** (a) 324 N. (b)  $270 \text{ N} \rightarrow$ .
- 4.28** (a) 400 N. (b)  $\mathbf{C} = 458 \text{ N} \searrow 49.1^\circ$ .
- 4.29** (a) 875 lb (b)  $1584 \text{ lb} \searrow 45.0^\circ$ .
- 4.30**  $T = 80.0 \text{ N}$ ;  $\mathbf{C} = 89.4 \text{ N} \searrow 26.6^\circ$ .
- 4.33**  $T = 2P/3$ ;  $\mathbf{C} = 0.577P \rightarrow$ .
- 4.34**  $T = 0.586P$ ;  $\mathbf{C} = 0.414P \rightarrow$ .
- 4.35**  $\mathbf{A} = 69.3 \text{ lb} \rightarrow$ ;  $\mathbf{B} = 34.6 \text{ lb} \swarrow 60.0^\circ$ ;  $\mathbf{C} = 173.2 \text{ lb} \searrow 60.0^\circ$ .
- 4.36**  $T_{BE} = 50.0 \text{ lb}$ ;  $\mathbf{A} = 18.75 \text{ lb} \rightarrow$ ;  $\mathbf{D} = 18.75 \text{ lb} \leftarrow$ .
- 4.37** (a) 1432 N. (b) 1100 N  $\uparrow$ . (c)  $1400 \text{ N} \leftarrow$ .
- 4.38**  $T_{BE} = 3230 \text{ N}$ ;  $T_{CF} = 960 \text{ N}$ ;  $\mathbf{D} = 3750 \text{ N} \leftarrow$ .
- 4.41**  $T = 80.0 \text{ N}$ ;  $\mathbf{A} = 160.0 \text{ N} \swarrow 30.0^\circ$ ;  $\mathbf{C} = 160.0 \text{ N} \searrow 30.0^\circ$ .
- 4.42**  $T = 69.3 \text{ N}$ ;  $\mathbf{A} = 140.0 \text{ N} \swarrow 30.0^\circ$ ;  $\mathbf{C} = 180.0 \text{ N} \searrow 30.0^\circ$ .
- 4.43** (a)  $\mathbf{A} = 78.5 \text{ N}$ ;  $\mathbf{M}_A = 125.6 \text{ N} \cdot \text{m} \uparrow$ .  
 (b)  $\mathbf{A} = 111.0 \text{ N} \searrow 45.0^\circ$ ;  $\mathbf{M}_A = 125.6 \text{ N} \cdot \text{m} \uparrow$ .  
 (c)  $\mathbf{A} = 157.0 \text{ N} \uparrow$ ;  $\mathbf{M}_A = 251 \text{ N} \cdot \text{m} \uparrow$ .
- 4.44**  $\mathbf{C} = 7.07 \text{ lb} \searrow 45.0^\circ$ ;  $\mathbf{M}_C = 43.0 \text{ lb} \cdot \text{in} \cdot \downarrow$ .
- 4.46**  $\mathbf{A} = 1848 \text{ N} \searrow 82.6^\circ$ ;  $\mathbf{M}_A = 1431 \text{ N} \cdot \text{m} \downarrow$ .
- 4.47** (a)  $\mathbf{D} = 20.0 \text{ lb} \downarrow$ ;  $\mathbf{M}_D = 20.0 \text{ lb} \cdot \text{ft} \uparrow$ .  
 (b)  $\mathbf{D} = 10.00 \text{ lb} \downarrow$ ;  $\mathbf{M}_D = 30.0 \text{ lb} \cdot \text{ft} \downarrow$ .
- 4.49**  $\mathbf{C} = 1951 \text{ N} \searrow 88.5^\circ$ ;  $\mathbf{M}_C = 75.0 \text{ N} \cdot \text{m} \downarrow$ .
- 4.50**  $1.232 \text{ kN} \leq T \leq 1.774 \text{ kN}$ .
- 4.51** (a)  $\theta = 2 \sin^{-1}(W/2P)$ . (b)  $\theta = 29.0^\circ$ .
- 4.52** (a)  $T = \frac{1}{2}W/(1 - \tan \theta)$ . (b)  $\theta = 39.8^\circ$ .
- 4.53** (a)  $\sin \theta + \cos \theta = M/Pl$ . (b)  $17.11^\circ$  and  $72.9^\circ$ .
- 4.54** (a)  $\cos^3 \theta = a(P + Q)/Pl$ . (b)  $40.6^\circ$ .
- 4.57**  $141.1^\circ$ .
- 4.58** (a)  $(1 - \cos \theta) \tan \theta = W/2kl$ . (b)  $49.7^\circ$ .
- 4.59** (1) completely constrained; determinate;  $\mathbf{A} = \mathbf{C} = 196.2 \text{ N} \uparrow$ .  
 (2) completely constrained; determinate;  $\mathbf{B} = 0$ ,  $\mathbf{C} = \mathbf{D} = 196.2 \text{ N} \uparrow$ .  
 (3) completely constrained; indeterminate;  $\mathbf{A}_x = 294 \text{ N} \rightarrow$ ;  
 $\mathbf{D}_x = 294 \text{ N} \leftarrow$ .  
 (4) improperly constrained; indeterminate; no equilibrium.  
 (5) partially constrained; determinate; equilibrium;  
 $\mathbf{C} = \mathbf{D} = 196.2 \text{ N} \uparrow$ .  
 (6) completely constrained; determinate;  $\mathbf{B} = 294 \text{ N} \rightarrow$ ;  
 $\mathbf{D} = 491 \text{ N} \searrow 53.1^\circ$ .  
 (7) partially constrained; no equilibrium.  
 (8) completely constrained; indeterminate;  $\mathbf{B} = 196.2 \text{ N} \uparrow$ ,  
 $\mathbf{D}_y = 196.2 \text{ N} \uparrow$ .
- 4.61**  $\mathbf{A} = 400 \text{ N} \uparrow$ ;  $\mathbf{B} = 500 \text{ N} \swarrow 53.1^\circ$ .
- 4.62**  $a \geq 138.6 \text{ mm}$ .
- 4.66**  $\mathbf{B} = 888 \text{ N} \swarrow 41.3^\circ$ ;  $\mathbf{D} = 943 \text{ N} \searrow 45.0^\circ$ .
- 4.67**  $\mathbf{B} = 1001 \text{ N} \searrow 48.2^\circ$ ;  $\mathbf{D} = 943 \text{ N} \swarrow 45.0^\circ$ .
- 4.69** (a) 499 N. (b)  $457 \text{ N} \searrow 26.6^\circ$ .
- 4.70** (a) 998 N. (b)  $822 \text{ N} \searrow 5.72^\circ$ .
- 4.71**  $\mathbf{A} = 37.1 \text{ lb} \searrow 62.4^\circ$ ;  $T = 18.57 \text{ lb}$ .
- 4.74** (a)  $24.9 \text{ lb} \searrow 30.0^\circ$ . (b)  $15.34 \text{ lb} \searrow 30.0^\circ$ .
- 4.75**  $T = 100.0 \text{ lb}$ ;  $\mathbf{B} = 111.1 \text{ lb} \swarrow 30.3^\circ$ .
- 4.77**  $\mathbf{A} = 170.0 \text{ N} \searrow 33.9^\circ$ ;  $\mathbf{C} = 160.0 \text{ N} \searrow 28.1^\circ$ .
- 4.80** (a)  $F_{AD} = 400 \text{ N}$ . (b)  $\mathbf{C} = 458 \text{ N} \searrow 49.1^\circ$ .
- 4.81** (a)  $2P \searrow 60.0^\circ$ . (b)  $1.239P \swarrow 36.2^\circ$ .
- 4.82** (a)  $1.155P \searrow 30.0^\circ$ . (b)  $1.086P \searrow 22.9^\circ$ .
- 4.83** 60.0 mm.
- 4.84**  $\tan \theta = 2 \tan \beta$ .
- 4.85** (a)  $49.1^\circ$ . (b)  $\mathbf{A} = 45.3 \text{ N} \leftarrow$ ;  $\mathbf{B} = 90.6 \text{ N} \searrow 60.0^\circ$ .
- 4.87** (a) 12.91 in. (b) 11.62 lb. (c) 5.92 lb.
- 4.88**  $32.5^\circ$ .
- 4.90** (a)  $59.4^\circ$ . (b)  $\mathbf{A} = 8.45 \text{ lb} \rightarrow$ ;  $\mathbf{B} = 13.09 \text{ lb} \searrow 49.8^\circ$ .

## CHAPTER 4

**4.1** (a) 325 lb  $\uparrow$ . (b) 1175 lb  $\uparrow$ .

**4.2** 42.0 N  $\uparrow$

**4.3** 0.264 m

**4.4** (a) 245 lb.  $\uparrow$ . (b) 140.0 lb.

**4.5** (a) 6.07 kN  $\uparrow$ . (b) 4.23 kN  $\uparrow$ .

**4.6** (a) 4.89 kN  $\uparrow$ . (b) 3.69 kN  $\uparrow$ .

**4.9**  $150.0 \text{ mm} \leq d \leq 400 \text{ mm}$ .

**4.11**  $6.00 \text{ kips} \leq P \leq 42.0 \text{ kips}$ .

**4.12**  $3.50 \text{ kN} \leq P \leq 86.0 \text{ kN}$ .

**4.14**  $2.00 \text{ in.} \leq a \leq 10.00 \text{ in.}$

**4.15** (a)  $F_{DE} = 600 \text{ N}$ . (b)  $\mathbf{C} = 1253 \text{ N} \searrow 69.8^\circ$ .

**4.17** (a) 80.0 lb  $\downarrow$ . (b) 216 lb  $\searrow 22.0^\circ$ .

**4.18** 232 lb.

**4.19** (a) 2.00 kN. (b) 2.32 kN  $\searrow 46.4^\circ$ .

**4.21** (a)  $\mathbf{A} = 150.0 \text{ N} \searrow 30.0^\circ$ ;  $\mathbf{B} = 150.0 \text{ N} \searrow 30.0^\circ$ .

(b)  $\mathbf{A} = 433 \text{ N} \swarrow 12.55^\circ$ ;  $\mathbf{B} = 488 \text{ N} \searrow 30.0^\circ$ .

**4.23** (a)  $\mathbf{A} = 44.7 \text{ lb} \searrow 26.6^\circ$ ;  $\mathbf{B} = 30.0 \text{ lb} \uparrow$ .

(b)  $\mathbf{A} = 30.2 \text{ lb} \searrow 41.4^\circ$ ;  $\mathbf{B} = 34.6 \text{ lb} \searrow 60.0^\circ$ .

- 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  $T_A = 30.0 \text{ lb}$ ;  $T_B = 10.00 \text{ lb}$ ;  $T_C = 40.0 \text{ lb}$ .
- 4.100  $(W_D)_{\min} = 40.0 \text{ lb}$ ;  $x = 0 \text{ in.}$ ;  $z = 30.0 \text{ in.}$
- 4.101  $T_A = 23.5 \text{ N}$ ;  $T_C = 11.77 \text{ N}$ ;  $T_D = 105.9 \text{ N}$ .
- 4.102 (a) 0.480 m. (b)  $T_A = 23.5 \text{ N}$ ;  $T_C = 0$ ;  $T_D = 117.7 \text{ N}$ .
- 4.105  $T_{BD} = T_{BE} = 1100 \text{ lb}$ ;  $\mathbf{A} = (1200 \text{ lb})\mathbf{i} - (560 \text{ lb})\mathbf{j}$ .
- 4.106  $T_{AD} = 2.60 \text{ kN}$ ;  $T_{AE} = 2.80 \text{ kN}$ ;  $\mathbf{C} = (1.800 \text{ kN})\mathbf{j} + (4.80 \text{ kN})\mathbf{k}$ .
- 4.107  $T_{AD} = 5.20 \text{ kN}$ ;  $T_{AE} = 5.60 \text{ kN}$ ;  $\mathbf{C} = (9.60 \text{ kN})\mathbf{k}$ .
- 4.108 (a)  $T_{DE} = T_{DF} = 262 \text{ lb}$ . (b)  $\mathbf{A} = -(801 \text{ lb})\mathbf{i} + (1544 \text{ lb})\mathbf{j}$ .
- 4.109 (a)  $T_{CD} = T_{CE} = 3.96 \text{ kN}$ . (b)  $\mathbf{A} = (6.67 \text{ kN})\mathbf{i} + (1.667 \text{ kN})\mathbf{j}$ .
- 4.110 (a)  $T_{CD} = 0.954 \text{ kN}$ ;  $T_{CE} = 5.90 \text{ kN}$ .  
(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  $T_{CF} = 200 \text{ N}$ ;  $T_{DE} = 450 \text{ N}$ ;  $\mathbf{A} = (160.0 \text{ N})\mathbf{i} + (270 \text{ N})\mathbf{k}$ ;  
 $\mathbf{M}_A = -(16.20 \text{ N} \cdot \text{m})\mathbf{i}$ .
- 4.125  $T_{BE} = 975 \text{ N}$ ;  $T_{CF} = 600 \text{ N}$ ;  $T_{DC} = 625 \text{ N}$ ;  $\mathbf{A} = (2100 \text{ N})\mathbf{i} + (175.0 \text{ N})\mathbf{j} - (375 \text{ N})\mathbf{k}$ .
- 4.126  $T_{BE} = 1950 \text{ N}$ ;  $T_{CF} = 0$ ;  $T_{DC} = 1250 \text{ N}$ ;  $\mathbf{A} = (3000 \text{ N})\mathbf{i} - (750 \text{ N})\mathbf{k}$ .
- 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 lb) $\mathbf{j}$
- 4.138 (a)  $x = 4.00 \text{ ft}$ ;  $y = 8.00 \text{ ft}$ . (b) 10.73 lb.
- 4.139 (a)  $x = 0 \text{ ft}$ ;  $y = 16.00 \text{ ft}$ . (b) 11.31 lb.
- 4.142 (a) 37.9 N  $\uparrow$ . (b) 373 N  $\uparrow$ .
- 4.143 (a)  $\mathbf{A} = 225 \text{ N} \uparrow$ ;  $\mathbf{C} = 641 \text{ N} \nearrow 20.6^\circ$ .  
(b)  $\mathbf{A} = 365 \text{ N} \nearrow 60.0^\circ$ ;  $\mathbf{B} = 844 \text{ N} \nearrow 22.0^\circ$ .
- 4.145 (a) 130.0 N, (b)  $224 \text{ N} \nearrow 2.05^\circ$ .
- 4.146  $\mathbf{C} = 7.97 \text{ lb} \rightarrow$ ;  $\mathbf{D} = 42.6 \text{ lb} \leftarrow$ ;  $\mathbf{E} = 69.3 \text{ lb} \nearrow 60.0^\circ$ .
- 4.148  $\mathbf{A} = 63.6 \text{ lb} \searrow 45.0^\circ$ ;  $\mathbf{C} = 87.5 \text{ lb} \searrow 59.0^\circ$ .
- 4.150  $T_{BD} = 780 \text{ N}$ ;  $T_{BE} = 390 \text{ N}$ ;  $\mathbf{A} = -(195.0 \text{ N})\mathbf{i} + (1170 \text{ N})\mathbf{j} + (130.0 \text{ N})\mathbf{k}$ .

- 4.152  $T_{FJ} = 0$ ;  $T_{DH} = 60.0 \text{ lb}$ ;  $T_{BC} = 80.0 \text{ lb}$ ;  $\mathbf{A} = (100.0 \text{ lb})\mathbf{i} - (48.0 \text{ lb})\mathbf{k}$ .
- 4.153 (a)  $\mathbf{A} = 0.745P \nearrow 63.4^\circ$ ;  $\mathbf{C} = 0.471P \searrow 45.0^\circ$ .  
(b)  $\mathbf{A} = 0.812P \nearrow 60.0^\circ$ ;  $\mathbf{C} = 0.503P \nearrow 36.2^\circ$ .  
(c)  $\mathbf{A} = 0.448P \searrow 60.0^\circ$ ;  $\mathbf{C} = 0.652P \nearrow 69.9^\circ$ .  
(d) improperly constrained; no equilibrium.
- 4.C1  $\theta = 20^\circ$ ;  $T = 114.8 \text{ lb}$ ;  $\theta = 70^\circ$ ;  $T = 127.7 \text{ lb}$ ;  
 $T_{\max} = 132.2 \text{ lb}$  at  $\theta = 50.4^\circ$ .
- 4.C2  $x = 600 \text{ mm}$ ;  $P = 31.4 \text{ N}$ ;  $x = 150 \text{ mm}$ ;  $P = 37.7 \text{ N}$ ;  
 $P_{\max} = 47.2 \text{ N}$  at  $x = 283 \text{ mm}$ .
- 4.C3  $\theta = 30^\circ$ ;  $W = 9.66 \text{ lb}$ ;  $\theta = 60^\circ$ ;  $W = 36.6 \text{ lb}$ ;  
 $W = 5 \text{ lb}$  at  $\theta = 22.9^\circ$  [Also at  $\theta = 175.7^\circ$ ].
- 4.C4  $\theta = 30^\circ$ ;  $W = 0.80 \text{ lb}$ ;  $\theta = 60^\circ$ ;  $W = 4.57 \text{ lb}$ ;  
 $W = 5 \text{ lb}$  at  $\theta = 62.6^\circ$  [Also at  $\theta = 159.6^\circ$ ].
- 4.C5  $\theta = 30^\circ$ ;  $m = 7.09 \text{ kg}$ ;  $\theta = 60^\circ$ ;  $m = 11.02 \text{ kg}$ .  
When  $m = 10 \text{ kg}$ ,  $\theta = 51.0^\circ$ .
- 4.C6  $\theta = 15^\circ$ ;  $T_{BD} = 10.30 \text{ kN}$ ,  $T_{BE} = 21.7 \text{ kN}$ ;  
 $\theta = 30^\circ$ ;  $T_{BD} = 5.69 \text{ kN}$ ,  $T_{BE} = 24.4 \text{ kN}$ ;  
 $T_{\max} = 26.5 \text{ kN}$  at  $\theta = 36.9^\circ$ .

## CHAPTER 5

- 5.1  $\bar{X} = 175.6 \text{ mm}$ ,  $\bar{Y} = 94.4 \text{ mm}$ .
- 5.2  $\bar{X} = 16.21 \text{ mm}$ ,  $\bar{Y} = 31.9 \text{ mm}$ .
- 5.3  $\bar{X} = 19.28 \text{ in.}$ ,  $\bar{Y} = 6.94 \text{ in.}$
- 5.4  $\bar{X} = 5.67 \text{ in.}$ ,  $\bar{Y} = 5.17 \text{ in.}$
- 5.5  $\bar{X} = 7.22 \text{ in.}$ ,  $\bar{Y} = 9.56 \text{ in.}$
- 5.6  $\bar{X} = 92.0 \text{ mm}$ ,  $\bar{Y} = 23.3 \text{ mm}$ .
- 5.9  $\bar{X} = -10.00 \text{ mm}$ ,  $\bar{Y} = 87.5 \text{ mm}$ .
- 5.10  $\bar{X} = -9.89 \text{ mm}$ ,  $\bar{Y} = -10.67 \text{ mm}$
- 5.11  $\bar{X} = 0$ ,  $\bar{Y} = 6.45 \text{ in.}$
- 5.12  $\bar{X} = 50.5 \text{ mm}$ ,  $\bar{Y} = 19.34 \text{ mm}$ .
- 5.14  $\bar{X} = \bar{Y} = 9.00 \text{ in.}$
- 5.16  $\bar{Y} = \frac{2}{3} \left( \frac{r_2^3 - r_1^3}{r_2^2 - r_1^2} \right) \left( \frac{2 \cos \alpha}{\pi - 2\alpha} \right)$
- 5.17  $\bar{Y} = \frac{r_1 + r_2}{\pi - 2\alpha} \cos \alpha$
- 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  $\bar{X} = 172.5 \text{ mm}$ ,  $\bar{Y} = 97.5 \text{ mm}$
- 5.26  $\bar{X} = 18.45 \text{ in.}$ ,  $\bar{Y} = 6.48 \text{ in.}$
- 5.28 (a)  $T = 5.09 \text{ lb}$ . (b)  $\mathbf{C} = 9.48 \text{ lb} \searrow 57.5^\circ$ .
- 5.29 0.739 m
- 5.30  $L = 0.204 \text{ m}$  or  $0.943 \text{ m}$
- 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  $\bar{x} = 1.629 \text{ in.}$ ,  $\bar{y} = 0.1853 \text{ in.}$
- 5.51  $a = 1.901 \text{ in.}$  or  $3.74 \text{ in.}$

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

## CHAPTER 6

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



- 6.12**  $F_{AB} = F_{FH} = 1500$  lb C;  $F_{AC} = F_{CE} = F_{EG} = F_{CH} = 1200$  lb T;  $F_{BC} = F_{FC} = 0$ ;  $F_{BD} = F_{DF} = 1200$  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;  $F_{DE} = F_{FC} = 2.50$  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**  $F_{FC} = 3.50$  kN T;  $F_{FH} = 5.03$  kN C;  $F_{CH} = 1.677$  kN T;  $F_{CI} = F_{IK} = F_{KL} = 3.35$  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**  $F_{FC} = 1400$  lb T;  $F_{FI} = 2010$  lb C;  $F_{CI} = 671$  lb C;  $F_{CJ} = 2430$  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;  $F_{CC} = 42.0$  kips C;  $F_{DE} = 22.0$  kips T;  $F_{DF} = 33.5$  kips T;  $F_{EC} = 0$ .
- 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;  $F_{CH} = 192.7$  kN C.
- 6.29** Truss of Prob. 6.33a is the only simple truss.
- 6.30** Truss of Prob. 6.32b 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**  $F_{EC} = 7500$  lb T;  $F_{FC} = 3900$  lb C;  $F_{FH} = 6000$  lb C
- 6.45**  $F_{BD} = 216$  kN T;  $F_{DE} = 270$  kN T.
- 6.46**  $F_{DC} = 459$  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**  $F_{EC} = 3.46$  kN T;  $F_{CH} = 3.78$  kN C;  $F_{HJ} = 3.55$  kN C.
- 6.51**  $F_{DF} = 10.48$  kips C;  $F_{DC} = 3.35$  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;  $F_{CI} = 6.00$  kN T.
- 6.55**  $F_{AD} = 13.5$  kN C;  $F_{CD} = 0$ ;  $F_{CE} = 56.1$  kN T.
- 6.56**  $F_{DC} = 75.0$  kN C;  $F_{FC} = 56.1$  kN T;  $F_{FH} = 69.7$  kN T.
- 6.57**  $F_{AB} = 8.20$  kips T;  $F_{AC} = 4.50$  kips T;  $F_{FC} = 11.60$  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**  $F_{BC} = 5.48$  kips T;  $F_{DC} = 1.825$  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  $\searrow$   $36.9^\circ$ . (b)  $125$  N  $\nearrow$   $36.9^\circ$ .
- 6.76**  $F_{BD} = 255$  N C;  $\mathbf{C}_x = 320.0$  N  $\rightarrow$ ;  $\mathbf{C}_y = 625$  N  $\uparrow$ .
- 6.77** (a)  $80.0$  lb T. (b)  $72.1$  lb  $\nearrow$   $16.1^\circ$ .
- 6.78** (a)  $80.0$  lb T. (b)  $72.1$  lb  $\searrow$   $16.1^\circ$ .
- 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)  $C_x = 100.0 \text{ lb} \leftarrow$ ,  $C_y = 100.0 \text{ lb} \uparrow$ ;  $D_x = 100.0 \text{ lb} \rightarrow$ ,  $D_y = 20.0 \text{ lb} \downarrow$ . (b)  $E_x = 100.0 \text{ lb} \leftarrow$ ,  $E_y = 180.0 \text{ lb} \uparrow$ .
- 6.104** (a)  $C_x = 100.0 \text{ lb} \leftarrow$ ,  $C_y = 60.0 \text{ lb} \uparrow$ ;  $D_x = 100.0 \text{ lb} \rightarrow$ ,  $D_y = 20.0 \text{ lb} \uparrow$ . (b)  $E_x = 100.0 \text{ lb} \leftarrow$ ,  $E_y = 140.0 \text{ lb} \uparrow$ .
- 6.107** (a)  $A_x = 200 \text{ kN} \rightarrow$ ,  $A_y = 122 \text{ kN} \uparrow$ . (b)  $B_x = 200 \text{ kN} \leftarrow$ ,  $B_y = 10.00 \text{ kN} \downarrow$ .
- 6.108** (a)  $A_x = 205 \text{ kN} \rightarrow$ ,  $A_y = 134.5 \text{ kN} \uparrow$ . (b)  $B_x = 205 \text{ kN} \leftarrow$ ,  $B_y = 5.50 \text{ kN} \uparrow$ .
- 6.109**  $B = 98.5 \text{ lb} \angle 24.0^\circ$ ;  $C = 90.6 \text{ lb} \angle 6.34^\circ$ .
- 6.110** (a)  $301 \text{ lb} \angle 48.4^\circ$ . (b)  $375 \text{ lb} T$ .
- 6.111**  $F_{AC} = \sqrt{2} P/6 C$ ;  $F_{BF} = 2\sqrt{2} P/3 C$ ;  $F_{DI} = \sqrt{2} P/3 C$ ;  $F_{EH} = \sqrt{2} P/6 T$ .
- 6.113**  $F_{AF} = P/4 C$ ;  $F_{BC} = F_{DC} = P/\sqrt{2} C$ ;  $F_{EH} = P/4 T$ .
- 6.115**  $F_{AF} = M_0/4a C$ ;  $F_{BC} = F_{DC} = M_0/\sqrt{2}a T$ ;  $F_{EH} = 3M_0/4a C$ .
- 6.116**  $F_{AF} = \sqrt{2} M_0/3a C$ ;  $F_{BC} = M_0/a T$ ;  $F_{DC} = M_0/a C$ ;  $F_{EH} = 2\sqrt{2} M_0/3a T$ .
- 6.117**  $E = P/5 \downarrow$ ;  $F = 8P/5 \uparrow$ ;  $G = 4P/5 \downarrow$ ;  $H = 2P/5 \uparrow$ .
- 6.118**  $A = P/15 \uparrow$ ;  $D = 2P/15 \uparrow$ ;  $E = 8P/15 \uparrow$ ;  $H = 4P/15 \uparrow$ .
- 6.119** (a)  $A = 2.06P \angle 14.04^\circ$ ;  $B = 2.06P \angle 14.04^\circ$ ; frame is rigid. (b) Frame is not rigid. (c)  $A = 1.25P \angle 36.9^\circ$ ;  $B = 1.031P \angle 14.04^\circ$ ; frame is rigid.
- 6.122** (a)  $(F_{BD})_y = 96.0 \text{ lb} \downarrow$ . (b)  $F_{BD} = 100.0 \text{ lb} \angle 73.7^\circ$ .
- 6.123** (a)  $(F_{BD})_y = 240 \text{ lb} \downarrow$ . (b)  $F_{BD} = 250 \text{ lb} \angle 73.7^\circ$ .
- 6.126** (a)  $746 \text{ N} \downarrow$ . (b)  $565 \text{ N} \angle 61.3^\circ$ .
- 6.127** (a)  $302 \text{ N} \downarrow$ . (b)  $682 \text{ N} \angle 61.3^\circ$ .
- 6.128**  $T_{DE} = 81.0 \text{ N}$ ;  $B = 216 \text{ N} \downarrow$ .
- 6.129** (a)  $21.0 \text{ kN} \leftarrow$ . (b)  $52.5 \text{ kN} \leftarrow$ .
- 6.130** (a)  $1143 \text{ N} \cdot \text{m} \downarrow$ . (b)  $457 \text{ N} \cdot \text{m} \downarrow$ .
- 6.131**  $832 \text{ lb} \cdot \text{in.} \uparrow$ .
- 6.132**  $360 \text{ lb} \cdot \text{in.} \uparrow$ .
- 6.133**  $195.0 \text{ kN} \cdot \text{m} \downarrow$ .
- 6.134**  $40.5 \text{ kN} \cdot \text{m} \uparrow$ .
- 6.137**  $208 \text{ N} \cdot \text{m} \downarrow$ .
- 6.138**  $18.43 \text{ N} \cdot \text{m} \downarrow$ .
- 6.139**  $F_{AE} = 800 \text{ N} T$ ;  $F_{DC} = 100.0 \text{ N} C$ .
- 6.140**  $P = 120.0 \text{ N} \downarrow$ ;  $Q = 110.0 \text{ N} \leftarrow$ .
- 6.142**  $F = 3290 \text{ lb} \angle 15.12^\circ$ ;  $D = 4450 \text{ lb} \leftarrow$ .
- 6.143**  $D = 30.0 \text{ kN} \leftarrow$ ;  $F = 37.5 \text{ kN} \angle 36.9^\circ$ .
- 6.144**  $D = 150.0 \text{ kN} \leftarrow$ ;  $F = 96.4 \text{ kN} \angle 13.50^\circ$ .
- 6.145** (a)  $475 \text{ lb}$ . (b)  $528 \text{ lb} \angle 63.3^\circ$ .
- 6.146**  $44.8 \text{ kN}$ .
- 6.148**  $8.45 \text{ kN}$ .
- 6.149**  $25.0 \text{ lb} \downarrow$ .
- 6.150**  $10.00 \text{ lb} \downarrow$ .
- 6.151**  $240 \text{ N}$ .
- 6.154** (a)  $14.11 \text{ kN} \angle 19.10^\circ$ . (b)  $19.79 \text{ kN} \angle 47.6^\circ$ .
- 6.155** (a)  $4.91 \text{ kips} C$ . (b)  $10.69 \text{ kips} C$ .
- 6.156** (a)  $2.86 \text{ kips} C$ . (b)  $9.43 \text{ kips} C$ .
- 6.159** (a)  $M_0 = (90.0 \text{ N} \cdot \text{m})\mathbf{i}$ . (b)  $A = 0$ ;  $B = 0$ ;  $M_B = -(72.0 \text{ N} \cdot \text{m})\mathbf{i}$ .
- 6.160** (a)  $27.0 \text{ mm}$ . (b)  $40.0 \text{ N} \cdot \text{m} \downarrow$ .
- 6.163**  $E_x = 100.0 \text{ kN} \rightarrow$ ,  $E_y = 154.9 \text{ kN} \uparrow$ ;  $F_x = 26.5 \text{ kN} \rightarrow$ ,  $F_y = 118.1 \text{ kN} \downarrow$ ;  $H_x = 126.5 \text{ kN} \leftarrow$ ,  $H_y = 36.8 \text{ kN} \downarrow$ .
- 6.164**  $F_{AB} = F_{AE} = 671 \text{ lb} T$ ;  $F_{AC} = F_{AD} = 1000 \text{ lb} C$ ;  $F_{BC} = F_{DE} = 600 \text{ lb} C$ ;  $F_{CD} = 200 \text{ lb} T$ .
- 6.166**  $F_{FC} = 5.23 \text{ kN} C$ ;  $F_{EC} = 0.1476 \text{ kN} C$ ;  $F_{EH} = 5.08 \text{ kN} T$ .
- 6.167**  $F_{KM} = 5.02 \text{ kN} T$ ;  $F_{LM} = 1.963 \text{ kN} C$ ;  $F_{LN} = 3.95 \text{ kN} C$ .
- 6.168**  $A_x = 25.0 \text{ kips} \leftarrow$ ,  $A_y = 20.0 \text{ kips} \uparrow$ ;  $B_x = 25.0 \text{ kips} \leftarrow$ ,  $B_y = 10.00 \text{ kips} \downarrow$ ;  $C_x = 50.0 \text{ kips} \rightarrow$ ,  $C_y = 10.00 \text{ kips} \downarrow$ .
- 6.170**  $A_x = 150.0 \text{ N} \leftarrow$ ,  $A_y = 250 \text{ N} \uparrow$ ;  $E_x = 150.0 \text{ N} \rightarrow$ ,  $E_y = 450 \text{ N} \uparrow$ .
- 6.171**  $A = 327 \text{ lb} \rightarrow$ ;  $B = 827 \text{ lb} \leftarrow$ ;  $D = 621 \text{ lb} \uparrow$ ;  $E = 246 \text{ lb} \uparrow$ .

- 6.172** (a)  $P = 109.8 \text{ N} \rightarrow$ . (b)  $126.8 \text{ N} T$ , (c)  $139.8 \text{ N} \angle 38.3^\circ$ .
- 6.175** (a)  $312 \text{ lb}$ . (b)  $135.0 \text{ lb} \cdot \text{in.} \downarrow$ .
- 6.C1** (a)  $\theta = 30^\circ$ :  $W = 472 \text{ lb}$ ,  $A_{AB} = 1.500 \text{ in}^2$ ,  $A_{AC} = A_{CE} = 1.299 \text{ in}^2$ ,  $A_{BC} = A_{BE} = 0.500 \text{ in}^2$ ,  $A_{BD} = 1.732 \text{ in}^2$ . (b)  $\theta_{\text{opt}} = 56.8^\circ$ :  $W = 312 \text{ lb}$ ,  $A_{AB} = 0.896 \text{ in}^2$ ,  $A_{AC} = A_{CE} = 0.491 \text{ in}^2$ ,  $A_{BC} = 0.500 \text{ in}^2$ ,  $A_{BE} = 0.299 \text{ in}^2$ ,  $A_{BD} = 0.655 \text{ in}^2$ .
- 6.C2** (a) For  $x = 9.75 \text{ m}$ ,  $F_{BH} = 3.19 \text{ kN} T$ . (b) For  $x = 3.75 \text{ m}$ ,  $F_{BH} = 1.313 \text{ kN} C$ . (c) For  $x = 6 \text{ m}$ ,  $F_{CH} = 3.04 \text{ kN} T$ .
- 6.C3**  $\theta = 30^\circ$ :  $M = 5860 \text{ lb} \cdot \text{ft} \uparrow$ ;  $A = 670 \text{ lb} \angle 75.5^\circ$ . (a)  $M_{\text{max}} = 8680 \text{ lb} \cdot \text{ft}$  when  $\theta = 65.9^\circ$ . (b)  $A_{\text{max}} = 1436 \text{ lb}$  when  $\theta = 68.5^\circ$ .
- 6.C4**  $\theta = 30^\circ$ :  $M_A = 1.669 \text{ N} \cdot \text{m} \uparrow$ ,  $F = 11.79 \text{ N}$ .  $\theta = 80^\circ$ :  $M_A = 3.21 \text{ N} \cdot \text{m} \uparrow$ ,  $F = 11.98 \text{ N}$ .
- 6.C5**  $d = 0.40 \text{ in.}$ :  $634 \text{ lb} C$ ;  $d = 0.55 \text{ in.}$ :  $286 \text{ lb} C$ ;  $d = 0.473 \text{ in.}$ :  $F_{AB} = 500 \text{ lb} C$ .
- 6.C6**  $\theta = 20^\circ$ :  $M = 31.8 \text{ N} \cdot \text{m}$ ;  $\theta = 75^\circ$ :  $M = 12.75 \text{ N} \cdot \text{m}$ ;  $\theta = 60.0^\circ$ :  $M_{\text{min}} = 12.00 \text{ N} \cdot \text{m}$ .

## CHAPTER 7

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



- 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)  $54.5^\circ$ . (b) 675 N · m.  
**7.56** (a) 0.311 m. (b) 193.0 N · m.  
**7.57** (a) 1.236. (b)  $0.1180wL^2$ .  
**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 ↘  $17.4^\circ$ . (b) 971 lb ↗  $34.5^\circ$ .  
**7.96** (a) 2670 lb ↗  $2.10^\circ$ . (b) 2810 lb ↗  $18.6^\circ$ .  
**7.97** (a)  $d_B = 1.733$  m;  $d_D = 4.20$  m. (b) 21.5 kN ↗  $3.81^\circ$ .  
**7.98** (a) 2.80 m. (b)  $\mathbf{A} = 32.0$  kN ↘  $38.7^\circ$ ;  $\mathbf{E} = 25.0$  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)  $56.5^\circ$ ;  $0.755wL$ .  
**7.154** (a) 1500 N. (b) (On AB)  $\mathbf{F} = 1324$  N ↑;  
 $\mathbf{V} = 706$  N ←;  $\mathbf{M} = 229$  N · m ↗.  
**7.155** (On B)  $\mathbf{F} = 250$  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  $\leq P \leq 479$  N.  
**8.6**  $143.0$  N  $\leq P \leq 483$  N.  
**8.7** (a) 105.8 N. (b)  $46.0^\circ$ .  
**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)  $136.4^\circ$ . (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**  $3.46 \leq \frac{L}{a} \leq 13.63$ .  
**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  $\leq P \leq 308$  N.  
**8.37**  $9.38$  N · m  $\leq M \leq 15.01$  N · m.

- 8.38**  $-46.8 \text{ N} \leq P \leq 34.3 \text{ N}$ .  
**8.39** (b) 2.69 lb.  
**8.41** 0.0949.  
**8.42** (a) System slides;  $P = 62.8 \text{ N}$ .  
 (b) System rotates about B;  $P = 73.2 \text{ N}$ .  
**8.43**  $35.8^\circ$ .  
**8.44**  $20.5^\circ$ .  
**8.45** 1.225W.  
**8.46** (a)  $\mathbf{P} = 56.6 \text{ lb} \leftarrow$ . (b)  $\mathbf{B}_x = 82.6 \text{ lb} \leftarrow$ ;  $\mathbf{B}_y = 96.0 \text{ lb} \downarrow$ .  
**8.47** (a)  $\mathbf{P} = 21.4 \text{ lb} \rightarrow$ . (b)  $\mathbf{B}_x = 122.2 \text{ lb} \leftarrow$ ;  $\mathbf{B}_y = 96.0 \text{ lb} \downarrow$ .  
**8.48**  $\mathbf{P} = 2080 \text{ N} \downarrow$ .  
**8.49**  $\mathbf{P} = 1966 \text{ N} \downarrow$ .  
**8.52** (a) 62.7 lb. (b) 62.7 lb.  
**8.53** 9.86 kN  $\leftarrow$ .  
**8.54** 913 N  $\leftarrow$ .  
**8.55** (a)  $28.1^\circ$ . (b)  $728 \text{ N} \angle 14.04^\circ$ .  
**8.56** 29.9 lb.  
**8.57** 67.4 N.  
**8.60** (b) 283 N  $\leftarrow$ .  
**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**  $1068 \text{ N} \cdot \text{m}$ .  
**8.70**  $4.18 \text{ N} \cdot \text{m}$ .  
**8.72**  $169.7 \text{ lb} \cdot \text{in}$ .  
**8.73**  $32.7 \text{ lb} \cdot \text{in}$ .  
**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**  $T_{AB} = 77.5 \text{ lb}$ ;  $T_{CD} = 72.5 \text{ lb}$ ;  $T_{EF} = 67.8 \text{ lb}$ .  
**8.85** 22.0 lb  $\leftarrow$ .  
**8.86** 1.948 lb  $\downarrow$ .  
**8.87** 18.01 lb  $\leftarrow$ .  
**8.88** (a) 4.80 kN. (b)  $1.375^\circ$ .  
**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**  $73.0 \text{ lb} \leq P \leq 1233 \text{ lb}$ .  
**8.107**  $35.1 \text{ N} \cdot \text{m}$   
**8.108** (a)  $27.0 \text{ N} \cdot \text{m}$  (b) 675 N.  
**8.109** (a)  $39.0 \text{ N} \cdot \text{m}$ . (b) 844 N.  
**8.110** 421 lb  $\cdot$  in.  
**8.111** 301 lb  $\cdot$  in.  
**8.112**  $44.9 \text{ N} \cdot \text{m} \uparrow$ .  
**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)  $30.3 \text{ lb} \cdot \text{in} \uparrow$ . (b)  $3.78 \text{ lb} \downarrow$ .  
**8.125** (a)  $17.23 \text{ lb} \cdot \text{in} \downarrow$ . (b)  $2.15 \text{ lb} \uparrow$ .  
**8.126** 0.350.  
**8.131** (a)  $51.0 \text{ N} \cdot \text{m}$ . (b) 875 N.  
**8.132** (a) 170.5 N. (b)  $14.04^\circ$ .  
**8.133**  $53.5^\circ$ .  
**8.135**  $6.35 \leq L/a \leq 10.81$ .  
**8.136** 0.0533.  
**8.138** 0.225.  
**8.139** (a) 620 N  $\leftarrow$ . (b)  $\mathbf{B}_x = 1390 \text{ N} \leftarrow$ ;  $\mathbf{B}_y = 1050 \text{ N} \downarrow$ .  
**8.140** (a) and (b) 50.4 lb.  
**8.142** (a) 0.238. (b) 218 N  $\downarrow$ .  
**8.C1**  $x = 500 \text{ mm}$ : 63.3 N;  $P_{\max} = 67.8 \text{ N}$  at  $x = 355 \text{ mm}$ .  
**8.C2**  $W_B = 10 \text{ lb}$ ;  $\theta = 46.4^\circ$ ;  $W_B = 70 \text{ lb}$ ;  $\theta = 21.3^\circ$ .  
**8.C3**  $\mu_A = 0.25$ ;  $M = 0.0603 \text{ N} \cdot \text{m}$ .  
**8.C4**  $\theta = 30^\circ$ :  $1.336 \text{ N} \cdot \text{m} \leq M_A \leq 2.23 \text{ N} \cdot \text{m}$ .  
**8.C5**  $\theta = 60^\circ$ ;  $\mathbf{P} = 16.40 \text{ lb} \downarrow$ ;  $R = 5.14 \text{ lb}$ .  
**8.C6**  $\theta = 20^\circ$ :  $10.39 \text{ N} \cdot \text{m}$ .  
**8.C7**  $\theta = 20^\circ$ : 30.3 lb; 13.25 lb.  
**8.C8** (a)  $x_0 = 0.600L$ ;  $x_m = 0.604L$ ;  $\theta_1 = 5.06^\circ$ . (b)  $\theta_2 = 55.4^\circ$ .

## 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**  $390 \times 10^3 \text{ mm}^4$ ; 21.9 mm.  
**9.32**  $46.0 \text{ in}^4$ ; 1.599 in.  
**9.33**  $64.3 \times 10^3 \text{ mm}^4$ ; 8.87 mm.  
**9.34**  $46.5 \text{ in}^4$ ; 1.607 in.  
**9.37**  $I = 9.50 \times 10^6 \text{ mm}^4$ ;  $d_2 = 60.0 \text{ mm}$ .  
**9.38**  $A = 6600 \text{ mm}^2$ ;  $\bar{I} = 3.72 \times 10^6 \text{ mm}^4$ .  
**9.39**  $\bar{I}_x = 150.0 \text{ in}^4$ ;  $\bar{I}_y = 300 \text{ in}^4$ .  
**9.41**  $\bar{I}_x = 1.874 \times 10^6 \text{ mm}^4$ ;  $\bar{I}_y = 5.82 \times 10^6 \text{ mm}^4$ .  
**9.42**  $\bar{I}_x = 48.9 \times 10^3 \text{ mm}^4$ ;  $\bar{I}_y = 8.35 \times 10^3 \text{ mm}^4$ .  
**9.43**  $\bar{I}_x = 191.3 \text{ in}^4$ ;  $\bar{I}_y = 75.2 \text{ in}^4$ .  
**9.44**  $\bar{I}_x = 18.13 \text{ in}^4$ ;  $\bar{I}_y = 4.51 \text{ in}^4$ .  
**9.45** (a)  $80.9 \times 10^6 \text{ mm}^4$ . (b)  $57.4 \times 10^6 \text{ mm}^4$ .  
**9.46** (a)  $12.16 \times 10^6 \text{ mm}^4$ . (b)  $9.73 \times 10^6 \text{ mm}^4$ .  
**9.49**  $\bar{I}_x = 260 \times 10^6 \text{ mm}^4$ ;  $\bar{k}_x = 144.6 \text{ mm}$ ;  $\bar{I}_y = 17.53 \times 10^6 \text{ mm}^4$ ;  
 $\bar{k}_y = 37.6 \text{ mm}$ .  
**9.50**  $\bar{I}_x = 254 \text{ in}^4$ ;  $\bar{k}_x = 4.00 \text{ in}$ ;  $\bar{I}_y = 102.1 \text{ in}^4$ ;  $\bar{k}_y = 2.54 \text{ in}$ .

- 9.51  $\bar{I}_x = 255 \times 10^6 \text{ mm}^4$ ;  $\bar{k}_x = 134.1 \text{ mm}$ ;  $\bar{I}_y = 100.0 \times 10^6 \text{ mm}^4$ ;  $\bar{k}_y = 83.9 \text{ mm}$ .
- 9.52 1.077 in.
- 9.53  $\bar{I}_x = 3.55 \times 10^6 \text{ mm}^4$ ;  $\bar{I}_y = 49.8 \times 10^6 \text{ mm}^4$ .
- 9.55  $\bar{I}_x = 745 \times 10^6 \text{ mm}^4$ ;  $\bar{I}_y = 91.3 \times 10^6 \text{ mm}^4$ .
- 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  $-1.760 \times 10^6 \text{ mm}^4$ .
- 9.72  $-21.6 \times 10^6 \text{ mm}^4$ .
- 9.74  $-0.380 \text{ in}^4$ .
- 9.75  $471 \times 10^3 \text{ mm}^4$ .
- 9.76  $-9010 \text{ in}^4$ .
- 9.78  $1.165 \times 10^6 \text{ mm}^4$ .
- 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  $\bar{I}_x = 103.5 \times 10^6 \text{ mm}^4$ ;  $\bar{I}_y = 97.9 \times 10^6 \text{ mm}^4$ ;  $\bar{I}_{x'y'} = -38.3 \times 10^6 \text{ mm}^4$ .
- 9.81  $\bar{I}_x = 1033 \text{ in}^4$ ;  $\bar{I}_y = 2020 \text{ in}^4$ ;  $\bar{I}_{x'y'} = -873 \text{ in}^4$ .
- 9.83  $\bar{I}_x = 0.236 \text{ in}^4$ ;  $\bar{I}_y = 1.244 \text{ in}^4$ ;  $\bar{I}_{x'y'} = 0.1132 \text{ in}^4$ .
- 9.85  $20.2^\circ$ ;  $1.754a^4$ ,  $0.209a^4$ .
- 9.86  $-17.11^\circ$ ;  $139.1 \times 10^6 \text{ mm}^4$ ,  $62.3 \times 10^6 \text{ mm}^4$ .
- 9.87  $29.7^\circ$ ;  $2530 \text{ in}^4$ ,  $524 \text{ in}^4$ .
- 9.89  $-23.7^\circ$  and  $66.3^\circ$ ;  $1.257 \text{ in}^4$ ,  $0.224 \text{ in}^4$ .
- 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  $\bar{I}_x = 103.5 \times 10^6 \text{ mm}^4$ ;  $\bar{I}_y = 97.9 \times 10^6 \text{ mm}^4$ ;  $\bar{I}_{x'y'} = -38.3 \times 10^6 \text{ mm}^4$ .
- 9.93  $\bar{I}_x = 1033 \text{ in}^4$ ;  $\bar{I}_y = 2020 \text{ in}^4$ ;  $\bar{I}_{x'y'} = -873 \text{ in}^4$ .
- 9.95  $\bar{I}_x = 0.236 \text{ in}^4$ ;  $\bar{I}_y = 1.244 \text{ in}^4$ ;  $\bar{I}_{x'y'} = 0.1132 \text{ in}^4$ .
- 9.97  $20.2^\circ$ ;  $1.754a^4$ ,  $0.209a^4$ .
- 9.98  $-17.11^\circ$ ;  $139.1 \times 10^6 \text{ mm}^4$ ,  $62.3 \times 10^6 \text{ mm}^4$ .
- 9.99  $-33.4^\circ$ ;  $22.1 \times 10^3 \text{ in}^4$ ,  $2490 \text{ in}^4$ .
- 9.100  $29.7^\circ$ ;  $2530 \text{ in}^4$ ,  $524 \text{ in}^4$ .
- 9.103 (a)  $-1.146 \text{ in}^4$ . (b)  $29.1^\circ$  clockwise. (c)  $3.39 \text{ in}^4$ .
- 9.104  $23.8^\circ$  clockwise;  $0.524 \times 10^6 \text{ mm}^4$ ,  $0.0917 \times 10^6 \text{ mm}^4$ .
- 9.105  $19.54^\circ$  counterclockwise;  $4.34 \times 10^6 \text{ mm}^4$ ,  $0.647 \times 10^6 \text{ mm}^4$ .
- 9.106 (a)  $25.3^\circ$ . (b)  $1459 \text{ in}^4$ ,  $40.5 \text{ in}^4$ .
- 9.107 (a)  $88.0 \times 10^6 \text{ mm}^4$ . (b)  $96.3 \times 10^6 \text{ mm}^4$ ,  $39.7 \times 10^6 \text{ mm}^4$ .
- 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  $837 \times 10^{-9} \text{ kg} \cdot \text{m}^2$ ;  $6.92 \text{ mm}$ .
- 9.128  $1.160 \times 10^{-6} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ ;  $0.341 \text{ in}$ .
- 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)  $20.6 \times 10^{-3} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ ; 2.27 in.
- 9.134 (a)  $\pi \rho l^2 \left[ 6a^2 \left( \frac{5a^2}{3l^2} + \frac{2a}{l} + 1 \right) + \frac{d^2 l}{4} \right]$ . (b) 0.1851.
- 9.135  $I_x = 26 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ ;  $I_y = 38.2 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ ;  $I_z = 17.55 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .
- 9.136  $I_x = 175.5 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ ;  $I_y = 309 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ ;  $I_z = 154.4 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .
- 9.137  $I_x = 745 \times 10^{-6} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ ;  $I_y = 896 \times 10^{-6} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ ;  $I_z = 304 \times 10^{-6} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ .
- 9.138  $I_x = 344 \times 10^{-6} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ ;  $I_y = 132.1 \times 10^{-6} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ ;  $I_z = 453 \times 10^{-6} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ .
- 9.141 (a)  $13.99 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ . (b)  $20.6 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .  
(c)  $14.30 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .
- 9.142  $0.1785 \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ .
- 9.144  $I_x = 38.1 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ ;  $k_x = 110.7 \text{ mm}$ .
- 9.145 (a)  $26.4 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ . (b)  $31.2 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .  
(c)  $8.58 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .
- 9.147  $I_x = 0.0392 \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ ;  $I_y = 0.0363 \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ ;  $I_z = 0.0304 \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ .
- 9.148  $I_x = 0.323 \text{ kg} \cdot \text{m}^2$ ;  $I_y = I_z = 0.419 \text{ kg} \cdot \text{m}^2$ .
- 9.149  $I_{xy} = 2.50 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ ;  $I_{yz} = 4.06 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ ;  $I_{zx} = 8.81 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .
- 9.150  $I_{xy} = 2.44 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ ;  $I_{yz} = 1.415 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ ;  $I_{zx} = 4.59 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .
- 9.151  $I_{xy} = -538 \times 10^{-6} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ ;  $I_{yz} = -171.4 \times 10^{-6} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ ;  $I_{zx} = 1120 \times 10^{-6} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ .
- 9.152  $I_{xy} = -1.726 \times 10^{-3} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ ;  $I_{yz} = 0.507 \times 10^{-3} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ ;  $I_{zx} = -2.12 \times 10^{-3} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ .
- 9.155  $I_{xy} = -8.04 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ ;  $I_{yz} = 12.90 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ ;  $I_{zx} = 94.0 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .
- 9.156  $I_{xy} = 0$ ;  $I_{yz} = 48.3 \times 10^{-6} \text{ kg} \cdot \text{m}^2$ ;  $I_{zx} = -4.43 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .
- 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  $I_{xy} = 47.9 \times 10^{-6} \text{ kg} \cdot \text{m}^2$ ;  $I_{yz} = 102.1 \times 10^{-6} \text{ kg} \cdot \text{m}^2$ ;  $I_{zx} = 64.1 \times 10^{-6} \text{ kg} \cdot \text{m}^2$ .
- 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  $18.17 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .
- 9.166  $11.81 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .
- 9.167  $5Wa^2/18g$ .
- 9.168  $4.41\gamma ta^4/g$ .
- 9.169  $281 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .
- 9.170  $0.354 \text{ kg} \cdot \text{m}^2$ .
- 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)  $(\theta_x)_1 = (\theta_x)_2 = 49.7^\circ$ ,  $(\theta_y)_1 = 113.7^\circ$ ;  
 $(\theta_x)_2 = 45.0^\circ$ ,  $(\theta_y)_2 = 90.0^\circ$ ,  $(\theta_z)_2 = 135.0^\circ$ ;  
 $(\theta_x)_3 = (\theta_x)_4 = 73.5^\circ$ ,  $(\theta_y)_3 = 23.7^\circ$ .
- 9.180 (a)  $K_1 = 14.30 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ ;  
 $K_2 = 13.96 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ ;  $K_3 = 20.6 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .  
(b)  $(\theta_x)_1 = (\theta_x)_2 = 90.0^\circ$ ,  $(\theta_z)_1 = 0$ ;  
 $(\theta_x)_2 = 3.42^\circ$ ,  $(\theta_y)_2 = 86.6^\circ$ ,  $(\theta_z)_2 = 90.0^\circ$ .  
 $(\theta_x)_3 = 93.4^\circ$ ,  $(\theta_y)_3 = 3.43^\circ$ ,  $(\theta_z)_3 = 90.0^\circ$ .
- 9.182 (a)  $K_1 = 0.1639Wa^2/g$ ;  $K_2 = 1.054Wa^2/g$ ;  $K_3 = 1.115Wa^2/g$ .  
(b)  $(\theta_x)_1 = 36.7^\circ$ ,  $(\theta_y)_1 = 71.6^\circ$ ,  $(\theta_z)_1 = 59.5^\circ$ ;  
 $(\theta_x)_2 = 74.9^\circ$ ,  $(\theta_y)_2 = 54.5^\circ$ ,  $(\theta_z)_2 = 140.5^\circ$ ;  
 $(\theta_x)_3 = 57.5^\circ$ ,  $(\theta_y)_3 = 138.8^\circ$ ,  $(\theta_z)_3 = 112.4^\circ$ .

- 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)  $(\theta_x)_1 = 85.0^\circ$ ,  $(\theta_y)_1 = 36.8^\circ$ ,  $(\theta_z)_1 = 53.7^\circ$ ;  
 $(\theta_x)_2 = 81.7^\circ$ ,  $(\theta_y)_2 = 54.7^\circ$ ,  $(\theta_z)_2 = 143.4^\circ$ ;  
 $(\theta_x)_3 = 9.70^\circ$ ,  $(\theta_y)_3 = 99.0^\circ$ ,  $(\theta_z)_3 = 86.3^\circ$ .
- 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)  $3.13 \times 10^6 \text{ mm}^4$ . (b)  $2.41 \times 10^6 \text{ mm}^4$ .
- 9.190**  $I_x = 634 \times 10^6 \text{ mm}^4$ ;  $I_y = 38.0 \times 10^6 \text{ mm}^4$ .
- 9.191**  $I_{xy} = -2.81 \text{ in}^4$ .
- 9.193** (a)  $7ma^2/18$ . (b)  $0.819ma^2$ .
- 9.195**  $I_x = 0.877 \text{ kg} \cdot \text{m}^2$ ;  $I_y = 1.982 \text{ kg} \cdot \text{m}^2$ ;  $I_z = 1.652 \text{ kg} \cdot \text{m}^2$ .
- 9.C1**  $\theta = 20^\circ$ ;  $I_x = 14.20 \text{ in}^4$ ,  $I_y = 3.15 \text{ in}^4$ ,  $I_{xy} = -3.93 \text{ in}^4$ .
- 9.C3** (a)  $\bar{I}_x = 371 \times 10^3 \text{ mm}^4$ ,  $\bar{I}_y = 64.3 \times 10^3 \text{ mm}^4$ ;  
 $\bar{k}_x = 21.3 \text{ mm}$ ,  $\bar{k}_y = 8.87 \text{ mm}$ . (b)  $\bar{I}_x = 40.4 \text{ in}^4$ ,  
 $\bar{I}_y = 46.5 \text{ in}^4$ ,  $\bar{k}_x = 1.499 \text{ in}$ ,  $\bar{k}_y = 1.607 \text{ in}$ .  
 (c)  $\bar{k}_x = 2.53 \text{ in}$ ,  $\bar{k}_y = 1.583 \text{ in}$ . (d)  $\bar{k}_x = 1.904 \text{ in}$ ,  
 $\bar{k}_y = 0.950 \text{ in}$ .
- 9.C5** (a)  $5.99 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ . (b)  $77.4 \times 10^{-3} \text{ kg} \cdot \text{m}^2$ .
- 9.C6** (a)  $74.0 \times 10^{-6} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ . (b)  $645 \times 10^{-6} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ .  
 (c)  $208 \times 10^{-6} \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ .

## CHAPTER 10

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

## CHAPTER 11

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

- 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<sup>4</sup>. (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<sup>2</sup>,  $1.832$  s<sup>-2</sup>.
- 11.17 (a)  $0.0900$  s<sup>-2</sup>. (b)  $\pm 16.97$  mm/s.
- 11.18 (a)  $48.0$  m<sup>3</sup>/s<sup>2</sup>. (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)  $\infty$ . (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)  $-2.75 \times 10^{-6}$  ft/s<sup>2</sup>. (c)  $49.9$  min.
- 11.28 (a)  $-0.0525$  m/s<sup>2</sup>. (b)  $6.17$  s.
- 11.31 (a)  $2.36 v_0 T$ ,  $\pi v_0/T$ . (b)  $0.363 v_0$ .
- 11.33 (a)  $1.500$  m/s<sup>2</sup>. (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<sup>2</sup>,  $2.06$  m/s<sup>2</sup>. (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<sup>2</sup>. (b)  $9.25$  ft/s<sup>2</sup>.
- 11.43 (a)  $3.00$  s. (b)  $4.00$  ft/s<sup>2</sup>.
- 11.44 (a)  $-0.250$  m/s<sup>2</sup>,  $0.300$  m/s<sup>2</sup>. (b)  $20.8$  s. (c)  $85.5$  km/h.
- 11.46 (a)  $17.36$  ft/s<sup>2</sup>  $\angle$ ,  $3.47$  ft/s<sup>2</sup>  $\angle$ . (b)  $20.1$  ft. (c)  $9.64$  ft/s.
- 11.47 (a)  $2.00$  m/s  $\uparrow$ . (b)  $2.00$  m/s  $\downarrow$ . (c)  $8.00$  m/s  $\uparrow$ .
- 11.48 (a)  $20.0$  m/s<sup>2</sup>  $\rightarrow$ ,  $6.67$  m/s<sup>2</sup>  $\downarrow$ . (b)  $13.33$  m/s  $\downarrow$ ,  $13.33$  m  $\downarrow$ .
- 11.49 (a)  $30.0$  ft/s  $\uparrow$ . (b)  $15.00$  ft/s  $\uparrow$ . (c)  $45.0$  ft/s  $\uparrow$ . (d)  $30.0$  ft/s  $\uparrow$ .
- 11.50 (a)  $2.40$  ft/s<sup>2</sup>  $\uparrow$ ,  $4.80$  ft/s<sup>2</sup>  $\downarrow$ . (b)  $12.00$  ft/s  $\uparrow$ .
- 11.53 (a)  $200$  mm/s  $\rightarrow$ . (b)  $600$  mm/s  $\rightarrow$ . (c)  $200$  mm/s  $\leftarrow$ .  
(d)  $400$  mm/s  $\rightarrow$ .
- 11.54 (a)  $13.33$  mm/s<sup>2</sup>  $\leftarrow$ ,  $20.0$  mm/s<sup>2</sup>  $\leftarrow$ . (b)  $13.33$  mm/s<sup>2</sup>  $\rightarrow$ .  
(c)  $70.0$  mm/s  $\rightarrow$ ,  $440$  mm  $\rightarrow$ .
- 11.55 (a)  $10.00$  mm/s  $\rightarrow$ , (b)  $6.00$  mm/s<sup>2</sup>  $\rightarrow$ ,  $2.00$  mm/s<sup>2</sup>  $\uparrow$ .  
(c)  $175$  mm  $\uparrow$ .
- 11.56 (a)  $240$  mm/s<sup>2</sup>  $\downarrow$ ,  $345$  mm/s<sup>2</sup>  $\uparrow$ . (b)  $130$  mm/s  $\rightarrow$ ,  $43.3$  mm/s  $\uparrow$ .  
(c)  $728$  mm  $\rightarrow$ .
- 11.57 (a)  $2.00$  in./s<sup>2</sup>  $\uparrow$ ,  $3.00$  in./s<sup>2</sup>  $\downarrow$ . (b)  $0.667$  s. (c)  $0.667$  in.  $\uparrow$ .
- 11.58 (a)  $(1 - 6t^2)/4$  in./s<sup>2</sup>. (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,  $a = 0$ ;  $10$  s  $< t < 26$  s,  $a = -5$  ft/s<sup>2</sup>;  
 $26$  s  $< t < 41$  s,  $a = 0$ ;  $41$  s  $< t < 46$  s,  $a = 3$  ft/s<sup>2</sup>;  
 $t > 46$  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<sup>2</sup>  $\uparrow$ .
- 11.66  $207$  mm/s
- 11.67 (a)  $10.5$  s. (b)  $v$ - $t$  and  $x$ - $t$  curves.
- 11.69  $3.96$  m/s<sup>2</sup>.
- 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<sup>2</sup>. (b)  $114.3$  in./s<sup>2</sup>.
- 11.86  $104$  ft.
- 11.89 (a)  $8.60$  mm/s  $\nabla$   $35.5^\circ$ ,  $17.20$  mm/s<sup>2</sup>  $\angle$   $35.5^\circ$ .  
(b)  $33.4$  mm/s  $\angle$   $8.6^\circ$ ,  $39.3$  mm/s<sup>2</sup>  $\angle$   $14.7^\circ$ .
- 11.90 (a)  $0$ ,  $159.1$  m/s<sup>2</sup>  $\nabla$   $82.9^\circ$ . (b)  $6.28$  m/s  $\rightarrow$ ,  $157.9$  m/s<sup>2</sup>  $\downarrow$ .
- 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<sup>2</sup>  $\nabla$   $63.4^\circ$ .
- 11.92 (a)  $2.00$  in./s,  $6.00$  in./s. (b) For  $v_{\min}$ ,  $t = 2N\pi$  s,  $x = 8N\pi$  in.,  
 $y = 2$  in.,  $\mathbf{v} = 2.00$  in./s  $\rightarrow$  or  $2.00$  in./s  $\leftarrow$ .  
For  $v_{\max}$ ,  $t = (2N + 1)\pi$  s,  $x = 4(2N + 1)\pi$ ,  $y = 6$  in.,  
 $\mathbf{v} = 6.00$  in./s  $\rightarrow$  or  $6.00$  in./s  $\leftarrow$ .
- 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<sup>2</sup>. (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  $\leq v_0 \leq 35.0$  ft/s.
- 11.100 (a)  $70.4$  mi/h  $\leq v_0 \leq 89.4$  mi/h. (b)  $6.89^\circ$ ,  $4.29^\circ$ .
- 11.101 (a)  $2.87$  m  $> 2.43$  m. (b)  $7.01$  m from the net.
- 11.102  $0.244$  m  $\leq h \leq 0.386$  m.
- 11.103  $726$  ft or  $242$  yd.
- 11.104  $0 \leq d \leq 1.737$  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  $\leq v_0 \leq 14.48$  m/s.
- 11.108  $0.678$  m/s  $\leq v_0 \leq 1.211$  m/s.
- 11.111 (a)  $4.90^\circ$ . (b)  $963$  ft. (c)  $16.24$  s.
- 11.112 (a)  $14.66^\circ$ . (b)  $0.1074$  s.
- 11.113 (a)  $10.38^\circ$ . (b)  $9.74^\circ$ .
- 11.115 (a)  $45.0^\circ$ ,  $6.52$  m. (b)  $58.2^\circ$ ,  $5.84$  m.
- 11.117 (a)  $1.540$  m/s  $\angle$   $38.6^\circ$ . (b)  $1.503$  m/s  $\angle$   $58.3^\circ$ .
- 11.118  $5.05$  m/s  $\nabla$   $55.8^\circ$ .
- 11.119  $1.737$  knots  $\nabla$   $18.41^\circ$ .
- 11.120 (a)  $2.67$  mi/h  $\nabla$   $12.97^\circ$ . (b)  $258$  mi/h  $\angle$   $76.4^\circ$ .  
(c)  $65$  m  $\nabla$   $40^\circ$ .
- 11.123 (a)  $8.53$  in./s  $\nabla$   $54.1^\circ$ . (b)  $6.40$  in./s<sup>2</sup>  $\nabla$   $54.1^\circ$ .
- 11.124 (a)  $7.01$  in./s  $\nabla$   $60^\circ$ . (b)  $11.69$  in./s<sup>2</sup>  $\nabla$   $60.6^\circ$ .
- 11.125 (a)  $0.835$  mm/s<sup>2</sup>  $\nabla$   $75^\circ$ . (b)  $8.35$  mm/s  $\nabla$   $75^\circ$ .
- 11.126 (a)  $0.958$  m/s<sup>2</sup>  $\nabla$   $23.6^\circ$ . (b)  $1.917$  m/s  $\nabla$   $23.6^\circ$ .
- 11.127  $10.54$  ft/s  $\nabla$   $81.3^\circ$ .
- 11.128 (a)  $5.18$  ft/s  $\nabla$   $15^\circ$ . (b)  $1.232$  ft/s  $\nabla$   $15^\circ$ .
- 11.129  $17.49$  km/h  $\angle$   $59.0^\circ$ .
- 11.130  $15.79$  km/h  $\nabla$   $26.0^\circ$ .
- 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<sup>2</sup>. (b)  $26.8$  mm/s<sup>2</sup>.
- 11.138 (a)  $178.9$  m. (b)  $1.118$  m/s<sup>2</sup>.
- 11.139  $2.53$  ft/s<sup>2</sup>.
- 11.141  $15.95$  ft/s<sup>2</sup>.
- 11.143 (a)  $281$  m. (b)  $209$  m.
- 11.144 (a)  $7.99$  m/s  $\angle$   $40^\circ$ . (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  $\angle$   $4.04^\circ$  and  $18.17$  m/s  $\nabla$   $4.04^\circ$ .
- 11.151  $(R^2 + c^2)/2\omega_n R$ .



- 11.152 2.50 ft.  
 11.153  $25.8 \times 10^3$  km/h.  
 11.154  $12.56 \times 10^3$  km/h.  
 11.155  $153.3 \times 10^3$  km/h.  
 11.156  $92.9 \times 10^6$  mi.  
 11.157  $885 \times 10^6$  mi.  
 11.158 1.606 h.  
 11.161 (a)  $3\pi b \mathbf{e}_\theta$ ,  $-4\pi^2 b \mathbf{e}_r$ . (b)  $\theta = 2N\pi$ ,  $N = 0, 1, 2, \dots$   
 11.162 (a)  $2b\omega$ ,  $4b\omega^2$ . (b)  $\rho = b$ , a circle.  
 11.163 (a)  $-(6\pi \text{ in./s}^2)\mathbf{e}_r$ ,  $(80 \pi \text{ in./s}^2)\mathbf{e}_\theta$ . (b) 0.  
 11.165 (a)  $(2\pi \text{ m/s})\mathbf{e}_\theta$ ,  $-(4\pi^2 \text{ m/s}^2)\mathbf{e}_r$   
 (b)  $-(\pi/2 \text{ m/s})\mathbf{e}_r + (\pi \text{ m/s})\mathbf{e}_\theta$ ,  $-(\pi^2/2 \text{ m/s}^2)\mathbf{e}_r - (\pi^2 \text{ m/s}^2)\mathbf{e}_\theta$ .  
 11.166 (a)  $2abt$ ,  $2ab\sqrt{1 + 4b^2t^4}$ . (b)  $\rho = a(\text{circle})$ .  
 11.169  $d\theta \tan \beta \sec \beta / (\tan \beta \cos \theta - \sin \theta)^2$ .  
 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,  $49.7^\circ$ .  
 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)  $\theta_x = 90^\circ$ ,  $\theta_y = 123.7^\circ$ ,  $\theta_z = 33.7^\circ$ . (b)  $\theta_x = 103.4^\circ$ ,  
 $\theta_y = 134.3^\circ$ ,  $\theta_z = 47.4^\circ$ .  
 11.182 (a) 1.00 s, 4.00 s. (b) 1.50 m, 24.5 m.  
 11.184 (a)  $-2.43 \times 10^6 \text{ ft/s}^2$ . (b)  $1.366 \times 10^{-3}$  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  $\mathbf{v}_A = 12.5 \text{ mm/s} \uparrow$ ,  $\mathbf{v}_B = 75 \text{ mm/s} \downarrow$ ,  
 $\mathbf{v}_C = 175 \text{ mm/s} \downarrow$ .  
 11.189 17.88 km/h  $\simeq 36.4^\circ$ .  
 11.190  $2.44 \text{ ft/s}^2$ .  
 11.193  $\dot{r} = 120 \text{ m/s}$ ,  $\ddot{r} = 34.8 \text{ m/s}^2$ ,  $\dot{\theta} = -0.0900 \text{ rad/s}$ ,  
 $\ddot{\theta} = -0.0156 \text{ rad/s}^2$ .

## CHAPTER 12

- 12.1 (a) 4.987 lb at  $0^\circ$ , 5.000 lb at  $45^\circ$ , 5.013 lb at  $90^\circ$ . (b) 5.000 lb at all latitudes. (c)  $0.1554 \text{ lb} \cdot \text{s}^2/\text{ft}$  at all latitudes.  
 12.2 (a) 3.24 N. (b) 2.00 kg.  
 12.3  $1.300 \times 10^6 \text{ kg} \cdot \text{m/s}$ .  
 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  $0.414 \text{ m/s}^2 \simeq 15^\circ$ .  
 12.11 (a) A:  $2.49 \text{ m/s}^2 \rightarrow$ , B:  $0.831 \text{ m/s}^2 \downarrow$ . (b) 74.8 N.  
 12.12 (a) A:  $0.698 \text{ m/s}^2 \rightarrow$ , B:  $0.233 \text{ m/s}^2 \downarrow$ . (b) 79.8 N.  
 12.15 (a)  $0.986 \text{ m/s}^2 \simeq 25^\circ$ . (b) 51.7 N.  
 12.16 (a)  $1.794 \text{ m/s}^2 \simeq 25^\circ$ . (b) 58.2 N.  
 12.17 (a)  $0.997 \text{ ft/s}^2 \simeq 15^\circ$ ,  $1.619 \text{ ft/s}^2 \simeq 15^\circ$ .  
 12.19 System 1: (a) 10.73 ft/s<sup>2</sup>. (b) 14.65 ft/s. (c) 1.864 s.  
 System 2: (a) 16.10 ft/s<sup>2</sup>. (b) 17.94 ft/s. (c) 1.242 s.  
 System 3: (a) 0.749 ft/s<sup>2</sup>. (b) 3.87 ft/s. (c) 26.7 s.  
 12.20 (a)  $1.962 \text{ m/s}^2 \uparrow$ . (b) 39.1 N.  
 12.21 (a)  $6.63 \text{ m/s}^2 \leftarrow$ . (b) 0.321 m  $\rightarrow$ .  
 12.22 (a)  $19.53 \text{ m/s}^2 \simeq 65^\circ$ . (b)  $4.24 \text{ m/s}^2 \simeq 65^\circ$ .  
 12.24  $0.347 m_0 v_0^3 / F_0$ .  
 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)  $\mathbf{a}_A = 4.76 \text{ m/s}^2 \rightarrow$ ,  $\mathbf{a}_B = 3.08 \text{ m/s}^2 \downarrow$ ,  
 $\mathbf{a}_C = 1.401 \text{ m/s}^2 \leftarrow$ .  
 12.29 (a) 36.0 N. (b)  $\mathbf{a}_A = 5.23 \text{ m/s}^2 \rightarrow$ ,  $\mathbf{a}_B = 2.62 \text{ m/s}^2 \downarrow$ ,  $\mathbf{a}_C = 0$ .  
 12.30 (a)  $\mathbf{a}_A = \mathbf{a}_B = \mathbf{a}_D = 2.76 \text{ ft/s}^2 \downarrow$ ,  $\mathbf{a}_C = 11.04 \text{ ft/s}^2 \uparrow$ .  
 (b) 18.80 lb.  
 12.31 (a) 24.2 ft/s  $\downarrow$ . (b) 17.25 ft/s  $\uparrow$ .  
 12.36 (a) 80.4 N. (b) 2.30 m/s.  
 12.37 (a)  $49.9^\circ$ . (b) 6.85 N.  
 12.38 8.25 ft/s.  
 12.40  $2.77 \text{ m/s} < v < 4.36 \text{ m/s}$ .  
 12.42  $9.00 \text{ ft/s} < v_C < 12.31 \text{ ft/s}$ .  
 12.43  $2.42 \text{ ft/s} < v < 13.85 \text{ ft/s}$ .  
 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  $\uparrow$ .  
 12.47 (a)  $6.95 \text{ ft/s}^2 \simeq 20^\circ$ . (b)  $8.87 \text{ ft/s}^2 \simeq 20^\circ$ .  
 12.48 (a) 2.905 N. (b)  $13.09^\circ$ .  
 12.49  $1126 \text{ N} \simeq 25.6^\circ$ .  
 12.50  $24.1^\circ \leq \theta \leq 155.9^\circ$ .  
 12.51 (a)  $43.9^\circ$ . (b) 0.390. (c) 78.8 km/h.  
 12.53 (a) 0.1858 W. (b)  $10.28^\circ$ .  
 12.55 468 mm.  
 12.56  $2.36 \text{ m/s} \leq v \leq 4.99 \text{ m/s}$ .  
 12.57 (a) 0.1904, motion impending downward.  
 (b) 0.349, motion impending upward.  
 12.58 (a) Does not slide. 1.926 lb  $\simeq 80^\circ$ .  
 (b) Slides downward. 1.123 lb  $\simeq 40^\circ$ .  
 12.61 (a) 0.1834. (b)  $10.39^\circ$  for impending motion to the left,  
 $169.6^\circ$  for impending motion to the right.  
 12.62 (a) 2.98 ft/s. (b)  $19.29^\circ$  for impending motion to the left,  
 $160.7^\circ$  for impending motion to the right.  
 12.64  $1.054 \sqrt{eV/mv_0^2}$ .  
 12.65 1.333 l.  
 12.66 (a)  $F_r = -10.73 \text{ N}$ ,  $F_\theta = 0.754 \text{ N}$ .  
 (b)  $F_r = -4.44 \text{ N}$ ,  $F_\theta = 1.118 \text{ N}$ .  
 12.67  $F_r = 0.0523 \text{ N}$ ,  $F_\theta = 0.432 \text{ N}$ .  
 12.68 (a)  $F_r = -1.217 \text{ lb}$ ,  $F_\theta = 0.248 \text{ lb}$ .  
 (b)  $F_r = -0.618 \text{ lb}$ ,  $F_\theta = -0.0621 \text{ lb}$ .  
 12.69 (a)  $mc^2(r_0 - kt) t^2$ . (b)  $mc(r_0 - 3kt)$ .  
 12.70 2.00 s.  
 12.71  $\mathbf{P} = (5.76 \text{ N}) \tan \theta \sec^3 \theta \simeq \theta$   
 $\mathbf{Q} = (5.76 \text{ N}) \tan^3 \theta \sec^3 \theta \rightarrow$   
 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)  $g = 24.8 \text{ m/s}^2$ .  
 12.80 (a) 35800 km and 22240 mi. (b) 3070 m/s and 10090 ft/s.  
 12.81  $4.13 \times 10^{21} \text{ lb} \cdot \text{s}^2/\text{ft}$ .  
 12.82 (a) 1 hr 57 min. (b) 3380 km.  
 12.84 (a)  $86.9 \times 10^{24} \text{ kg}$ . (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<sup>2</sup>. (c) 32.0 in./s.  
 12.91 (a) 24.0 in./s. (b)  $a_r = -258 \text{ in./s}^2$ ,  $a_\theta = 0$ . (c)  $-226 \text{ in./s}^2$ .  
 12.98 10.42 km/s.  
 12.99 (a) 10.13 km/s. (b) 2.97 km/s.  
 12.103 (a)  $26.3 \times 10^3 \text{ ft/s}$ . (b) 448 ft/s.  
 12.104  $\sqrt{2/(2 + \alpha)}$ .  
 12.105 (a)  $52.4 \times 10^3 \text{ ft/s}$ . (b) 1318 ft/s at A, 3900 ft/s at B.  
 12.108 98.0 h.  
 12.109 4.95 h.  
 12.110  $54.0^\circ$ .

- 12.112**  $5.31 \times 10^9$  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)  $609 \times 10^{12}$  m.  
**12.120** Show . . . .  
**12.121** Derive . . . .  
**12.122** 267 ft.  
**12.124** (a) 1.656 lb. (b) 20.8 lb.  
**12.125** (a)  $20.49 \text{ ft/s}^2 \nearrow 30^\circ$ . (b)  $17.75 \text{ ft/s}^2 \rightarrow$ .  
**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  $\searrow 70^\circ$ ,  $\mathbf{Q} = 14.00$  lb  $\nearrow 40^\circ$ .  
**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**  $4.54 \times 10^9$  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)  $8.57 \text{ m/s} \searrow 15^\circ$ . (b)  $5.30 \text{ m/s} \nearrow 15^\circ$ .  
**13.10** (a) 8.70 m. (b)  $4.94 \text{ m/s} \nearrow 15^\circ$ .  
**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  $\leftarrow$ . (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  $\downarrow$ . (b) 17.94 ft/s  $\downarrow$ .  
**13.24** (a)  $11.35 \text{ ft/s} \nearrow 23.6^\circ$ . (b)  $16.05 \text{ ft/s} \nearrow 23.6^\circ$ .  
**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.  $\downarrow$ . (b) 8.51 in./s  $\uparrow$  or  $\downarrow$ .  
**13.33**  $0.759 \sqrt{\rho a A/m}$ .  
**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  $\uparrow$ . (b) 30.4 mm, 104.9 N  $\uparrow$ .  
**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)  $k_1 k_2 / (k_1 + k_2)$ . (b)  $k_1 + k_2$ .  
**13.56** (a)  $x_0 \sqrt{k_1 k_2 / m(k_1 + k_2)}$ . (b)  $x_0 \sqrt{(k_1 + k_2) / m}$ .  
**13.57** 3.19 m/s  $\rightarrow$  or 3.19 m/s  $\leftarrow$ .  
**13.58** (a) 3.34 ft/s. (b)  $27.7 \text{ ft/s}^2$ .  
**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  $\downarrow$ .  
**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  $\leftarrow$ , 13.77 lb  $\uparrow$ .  
**13.74** (1): (a) 7.99 m/s. (b) 5.89 N  $\leftarrow$ .  
 (2): (a) 7.67 m/s. (b) 3.92 N  $\leftarrow$ .  
**13.75** (a) Loop 1: minimum  $v_C = 3.84 \text{ m/s} > 3.5 \text{ m/s}$ .  
 (b) Loop 2:  $v_0 = 7.83 \text{ m/s}$ .  
**13.78** (a)  $\cot \phi = 4.113 / (12 - y)$ .  
 (b)  $\theta_x = 85.7^\circ$ ,  $\theta_y = 71.6^\circ$ ,  $\theta_z = 161.1^\circ$ .  
**13.80** (b)  $V = -\ln xyz + C$ .  
**13.81** (a)  $\pi k a^2 / 4$ . (b) 0.  
**13.82** (a)  $F_x = x(x^2 + y^2 + z^2)^{-1/2}$ ,  $F_y = y(x^2 + y^2 + z^2)^{-1/2}$ ,  
 $F_z = z(x^2 + y^2 + z^2)^{-1/2}$ . (b)  $a\sqrt{3}$ .  
**13.85** (a) 90.46 J. (b) 2086 J.  
**13.86** 57.5 MJ/kg.  
**13.87**  $15.65 \times 10^3$  mi/h.  
**13.88**  $450 \times 10^3$  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**  $v_r = 9.05 \text{ ft/s}$ ,  $v_\theta = 9.14 \text{ ft/s}$ .  
**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**  $21.8 \times 10^6 \text{ ft}^2/\text{s}^2$   
**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)  $11.32 \times 10^3 \text{ ft/s}$ . (b)  $13.68 \times 10^3 \text{ ft/s}$ .  
**13.110** 58.9°.  
**13.111** (a) 31.5 m/s. (b) 1053 m/s.  
**13.116** (b)  $v_{\text{esc}} \sqrt{\alpha / (1 + \alpha)} \leq v_0 \leq v_{\text{esc}} \sqrt{(1 + \alpha) / (2 + \alpha)}$ .  
**13.118** (a)  $h = r_{\text{min}} v_{\text{max}}$ ,  $E/m = \frac{1}{2} v_{\text{max}}^2 - GM/r_{\text{min}}$ .  
**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)  $-(125.5 \text{ m/s})\mathbf{j} - (194.5 \text{ m/s})\mathbf{k}$ .  
**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  $\leftarrow$ . (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  $\uparrow$ . (b) 0.500 N  $\cdot$  s  $\uparrow$ .  
**13.152**  $mMv_0 \cos \theta / (m + M) \rightarrow$ ,  $mv_0 \sin \theta \uparrow$ .  
**13.154** 76.9 lb.  
**13.155** (a)  $v'_A = 0.363$  m/s  $\leftarrow$ ,  $v'_B = 2.44$  m/s  $\rightarrow$ . (b) 4.13 J.  
**13.157** 0.800.  
**13.158** (a)  $v'_A = 10.38$  ft/s  $\rightarrow$ ,  $v'_B = 7.38$  ft/s  $\rightarrow$ . (b) 0.0611 ft  $\cdot$  lb.  
**13.159** A: 1.013 m/s  $\leftarrow$ , B: 0.338 m/s  $\leftarrow$ , C: 0.150 m/s  $\leftarrow$ .  
**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**  $0.728 \leq e \leq 0.762$ .  
**13.165**  $v'_A = 6.37$  m/s  $\nearrow 77.2^\circ$ ,  $v'_B = 1.802$  m/s  $\nearrow 40^\circ$ .  
**13.166**  $v'_A = 3.00$  m/s  $\nearrow 40^\circ$ ,  $v'_B = 3.00$  m/s  $\nearrow 40^\circ$ .  
**13.167** (a)  $v_A = 0.848 v_0 \searrow 27.0^\circ$ ,  $v_B = 0.456 v_0 \nearrow 57.6^\circ$ .  
**13.168** (a)  $70.0^\circ$ . (b) 0.972 ft/s  $\rightarrow$ .  
**13.169** 0.857.  
**13.170** 15.94 m.  
**13.173** (a)  $22.5^\circ$ . (b)  $21.3^\circ$ .  
**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  $\rightarrow$  for  $e = 1$ , 2.50 m/s  $\rightarrow$  for  $e = 0$ .  
**13.176** (a)  $v'_A = v'_B = 0$ . (b)  $v'_A = 1.201$  m/s  $\rightarrow$ ,  $v'_B = 0.400$  m/s  $\rightarrow$ .  
**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. (c) 0.263 ft.  
**13.183** (a) 2.90 m/s. (b) 100.5 J.  
**13.184** (a) 401 mm. (b) 4.10 N  $\cdot$  s.  
**13.185** (a) 0.923. (b) 1.278 m.  
**13.188**  $v'_A = 1.093$  ft/s  $\leftarrow$ ,  $v'_B = 3.28$  ft/s  $\rightarrow$ .  
**13.190** 1.688 ft  $\cdot$  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  $\rightarrow$ . (b) 1.417 m/s  $\rightarrow$ .  
**14.2** (a) 10.00 kg. (b) 1.200 m/s  $\rightarrow$ .  
**14.3** (a) 9.20 ft/s  $\leftarrow$ . (b) 9.37 ft/s  $\leftarrow$ .  
**14.4** (a) 2.80 ft/s  $\leftarrow$ . (b) 0.229 ft/s  $\leftarrow$ .  
**14.7** (a) A: 1.288 m/s  $\leftarrow$ , B: 0.312 m/s  $\rightarrow$ , C: 1.512 m/s  $\rightarrow$ .  
 (b) A: 0.956 m/s  $\leftarrow$ , B: 0.0296 m/s  $\leftarrow$ , C: 1.552 m/s  $\rightarrow$ .  
**14.8** 0.294 m/s  $\leftarrow$ .  
**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)  $-(26.0 \text{ kg} \cdot \text{m}/\text{s})\mathbf{i} + (14.00 \text{ kg} \cdot \text{m}/\text{s})\mathbf{j} + (14.00 \text{ kg} \cdot \text{m}/\text{s})\mathbf{k}$ .  
 (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  $\cdot$  lb, man: 447 ft  $\cdot$  lb.  
**14.34** (a) 1116 ft  $\cdot$  lb. (b) 623 ft  $\cdot$  lb.  
**14.37** (a)  $\mathbf{v}_B = m_A v_0 / (m_A + m_B) \rightarrow$ . (b)  $h = m_B v_0^2 / 2g (m_A + m_B)$ .  
**14.38** (a)  $\mathbf{v}_A = 0.200 v_0 \leftarrow$ ,  $\mathbf{v}_B = 0.693 v_0 \nearrow 30^\circ$ ,  
 $\mathbf{v}_C = 0.693 v_0 \searrow 30^\circ$ . (b)  $\mathbf{v}_A = 0.250 v_0 \nearrow 60^\circ$ ,  
 $\mathbf{v}_B = 0.866 v_0 \nearrow 30^\circ$ ,  $\mathbf{v}_C = 0.433 v_0 \searrow 30^\circ$ .  
**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**  $v_A = 4.11$  m/s  $\nearrow 46.9^\circ$ ,  $v_B = 17.39$  m/s  $\searrow 16.7^\circ$ .  
**14.42**  $v_A = 12.17$  m/s  $\nearrow 25.3^\circ$ ,  $v_B = 9.17$  m/s  $\searrow 70.9^\circ$ .  
**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  $\uparrow$ ,  $\mathbf{v}_B = 4.24$  m/s  $\searrow 31.9^\circ$ . (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  $\nearrow 53.1^\circ$ ,  $\mathbf{v}_C = 7.68$  ft/s  $\rightarrow$ . (b) 42.0 in.  
**14.54** (a)  $\mathbf{v}_A = 7.20$  ft/s  $\downarrow$ ,  $\mathbf{v}_B = 9.00$  ft/s  $\nearrow 53.1^\circ$ . (b) 74.0 in.  
**14.57** 312 N.  
**14.58** 4.18 m/s.  
**14.59** 90.6 N  $\leftarrow$ .  
**14.60** (a)  $F_x = 3280$  lb. (b)  $F_z = 6450$  lb.  
**14.63**  $\mathbf{C} = 161.7$  N  $\uparrow$ ,  $\mathbf{D}_x = 154.8$  N  $\rightarrow$ ,  $\mathbf{D}_y = 170.2$  N  $\uparrow$ .  
**14.67** (a) 61.1 m/s. (b) 59.8 N  $\searrow 49.0^\circ$ .  
**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<sup>3</sup>/s. (c) 43800 ft  $\cdot$  lb/s  
**14.84** 646 ft<sup>3</sup>/s.  
**14.85** (a)  $P = qv$ .  
**14.86** Case 1. (a) 0.333 g  $\downarrow$ . (b)  $0.817\sqrt{gl} \downarrow$ .  
 Case 2. (a)  $gy/l \downarrow$ . (b)  $\sqrt{gl} \downarrow$ .  
**14.87** (a)  $(m/l)(v^2 + gy)$ . (b)  $mg(1 - y/l) \uparrow$ .  
**14.88** (a)  $mgy/l$ . (b)  $(m/l)[g(l - y) + v^2] \uparrow$ .  
**14.89** 10.10 ft/s.  
**14.90** 4.75 ft/s.  
**14.92** 533 kg/s.  
**14.93** (a) 90.0 m/s<sup>2</sup>. (b)  $35.9 \times 10^3$  km/h.



- 14.94 (a)  $31.9 \text{ m/s}^2 \uparrow$ . (b)  $240 \text{ m/s}^2 \uparrow$ .  
 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)  $\mathbf{v}_A = \mathbf{v}_B = \mathbf{v}_C = 0.400 \text{ mi/h} \rightarrow$ .  
 (b)  $\mathbf{v}_A = \mathbf{v}_B = 1.68 \text{ mi/h} \leftarrow$ ,  $\mathbf{v}_C = 4.56 \text{ mi/h} \rightarrow$ .  
 14.109  $\mathbf{v}_A = 15.38 \text{ ft/s} \rightarrow$ ,  $\mathbf{v}_B = 5.13 \text{ ft/s} \leftarrow$ .  
 14.111 (a)  $qv_0 \leftarrow$ . (b)  $\sqrt{2gh} \leq 30^\circ$ .  
 14.112 1.712 kN  $\uparrow$  at C, 2.29 kN  $\uparrow$  at D.  
 14.113 414 rpm.  
 14.114  $v^2/g$ .  
 14.115 (a)  $m_0 + qt_L = m_0 e^{qL/m_0 v_0}$  (b)  $v_L = v_0 e^{-qL/m_0 v_0}$

## CHAPTER 15

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

- 15.111 (a) 5410 ft/s<sup>2</sup> ↓. (b) 5410 ft/s<sup>2</sup> ↑ (c) 5410 ft/s<sup>2</sup> ↖ 60°.
- 15.112 (a) 96.0 rad/s<sup>2</sup> ↗, 2.40 m/s<sup>2</sup> ←.  
(b) 48.0 rad/s<sup>2</sup> ↗, 1.200 m/s<sup>2</sup> ←.
- 15.113 (a) 300 mm/s<sup>2</sup> →. (b) 247 mm/s<sup>2</sup> ↗ 14.0°.
- 15.115 A: 56.6 in./s<sup>2</sup> ↘ 58.0°; B: 80.0 in./s<sup>2</sup> ↑;  
C: 172.2 in./s<sup>2</sup> ↘ 25.8°.
- 15.116 A: 48.0 in./s<sup>2</sup> ↑; B: 85.4 in./s<sup>2</sup> ↘ 69.4°;  
C: 82.8 in./s<sup>2</sup> ↗ 65.0°.
- 15.118 (a) 13.35 in./s<sup>2</sup> ↗ 61.0°. (b) 12.62 in./s<sup>2</sup> ↗ 64.0°.
- 15.119 (a) 92.5 in./s<sup>2</sup>. (b) 278 in./s<sup>2</sup>.
- 15.120 (a) 59.8 m/s<sup>2</sup> ↑. (b) 190.6 in./s<sup>2</sup> ↑.
- 15.121 D: 1558 m/s<sup>2</sup> ↖ 45°; E: 337 m/s<sup>2</sup> ↗ 45°.
- 15.122 (a) 1218 in./s<sup>2</sup> ←. (b) 993 in./s<sup>2</sup> ←.
- 15.125 148.3 m/s<sup>2</sup> ↓.
- 15.126 296 m/s<sup>2</sup> ↑.
- 15.127 (a) 1080 rad/s<sup>2</sup> ↓. (b) 460 ft/s<sup>2</sup> ↘ 64.9°.
- 15.128 (a) 432 rad/s<sup>2</sup> ↗. (b) 272 ft/s<sup>2</sup> ↘ 60.3°.
- 15.129 1.745 m/s<sup>2</sup> ↗ 68.2°.
- 15.130 (a) 7.20 rad/s<sup>2</sup>. (b) 1.296 m/s<sup>2</sup> ←.
- 15.132 9.60 m/s<sup>2</sup> →.
- 15.133 (a) 10.75 rad/s<sup>2</sup> ↗. (b) 2.30 rad/s<sup>2</sup> ↗.
- 15.135 (a) 8.15 rad/s<sup>2</sup> ↗. (b) 0.896 rad/s<sup>2</sup>.
- 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  $bv_A / (b^2 + x_A^2) \uparrow, 2b_A x_A v_A^2 / (b^2 + x_A^2)^2$
- 15.143  $v[1 - \cos(vt/r)], v \sin(vt/r)$ .
- 15.146  $v_0 \sin^2 \theta / r \cos \theta \uparrow$ .
- 15.147  $(v_0/r)^2 (1 + \cos^2 \theta) + \tan^3 \theta \uparrow$ .
- 15.149  $(R\omega \sin \omega t)\mathbf{j}, (R\omega^2 \cos \omega t)\mathbf{j}$
- 15.150 (a) 1.815 rad/s ↓. (b) 16.42 in./s ↖ 20°.
- 15.151 (a) 5.16 rad/s ↓. (b) 1.339 in./s ↘ 60°.
- 15.152 AP: 4.68 rad/s ↗; BE: 1.415 rad/s ↗.
- 15.153 AD: 2.52 rad/s ↓; BP: 1.299 rad/s ↓.
- 15.156 (a)  $\mathbf{v}_{H/AE} = l\omega \leftarrow, \mathbf{v}_{H/BD} = 0$ . (b)  $\mathbf{v}_{H/AE} = 0.577 l\omega \searrow 30^\circ,$   
 $\mathbf{v}_{H/BD} = 0.577 l\omega \searrow 30^\circ$ .
- 15.157  $\mathbf{v}_{H/AE} = 0.299 l\omega \searrow 45^\circ, \mathbf{v}_{H/BD} = 0.816 l\omega \searrow 15^\circ$ .
- 15.160 (a) 0.520 m/s ↖ 82.6°. (b) 50.0 mm/s<sup>2</sup> ↘ 9.8°.
- 15.161 (a) 0.520 m/s ↖ 37.4°. (b) 50.0 mm/s<sup>2</sup> ↗ 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<sup>2</sup> west.
- 15.166 (a) 68.1 in./s<sup>2</sup> ↘ 21.5°. (b) 101.4 in./s<sup>2</sup> ↘ 3.2°.
- 15.167 (a) 95.2 in./s<sup>2</sup> ↗ 48.3°. (b) 57.5 in./s ↗ 64.3°.
- 15.168 Link 1: 303 mm/s<sup>2</sup> →; Link 2: 168.5 mm/s<sup>2</sup> ↗ 57.7°.
- 15.169 Link 3: 483 mm/s<sup>2</sup> ←; Link 4: 168.5 mm/s<sup>2</sup> ↘ 57.7°.
- 15.171 392 in./s<sup>2</sup> ↗ 4.05°.
- 15.174 (a)  $\mathbf{a}_A = 0.621 \text{ m/s}^2 \uparrow$ . (b)  $\mathbf{a}_B = 1.733 \text{ m/s}^2 \searrow 53.9^\circ$ .  
(c)  $\mathbf{a}_C = 2.62 \text{ m/s}^2 \searrow 67.6^\circ$ .
- 15.175 1.500 rad/s ↗, 7.79 rad/s<sup>2</sup> ↗.
- 15.176 6.00 rad/s ↗, 62.4 rad/s<sup>2</sup> ↓.
- 15.177 43.0 rad/s<sup>2</sup> ↓.
- 15.178 47.0 rad/s<sup>2</sup> ↓.
- 15.181 (a) 2.40 rad/s ↓, 34.6 rad/s<sup>2</sup> ↓.  
(b) 1.342 m/s ↘ 63.4°, 9.11 m/s<sup>2</sup> ↖ 18.4°.
- 15.182 (a) 3.61 rad/s ↗. (b) 86.6 in./s ↗ 30°. (c) 563 in./s<sup>2</sup> ↗ 46.1°.
- 15.183 (a) 3.61 rad/s ↓. (b) 86.6 in./s ↗ 30°. (c) 563 in./s<sup>2</sup> ↗ 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  $(\omega_1 / \cos 25^\circ) (-\sin 25^\circ \mathbf{j} + \cos 25^\circ \mathbf{k})$
- 15.211  $\omega_1 / \cos 25^\circ (-\sin 25^\circ \mathbf{j} + \cos 25^\circ \mathbf{k})$
- 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)  $51.3 \text{ in./s}^2 \downarrow$ . (b)  $184.9 \text{ in./s}^2 \nearrow 16.1^\circ$ .
- 15.249** (a)  $-1.824 \text{ rad/s}^2$ . (b)  $103.3 \text{ s}$ .
- 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)  $37.5 \text{ in./s} \rightarrow$ . (b)  $187.5 \text{ in./s}^2 \uparrow$ .
- 15.254**  $49.4 \text{ m/s}^2 \nwarrow 26.0^\circ$ .
- 15.256**  $(7.84 \text{ in./s})\mathbf{k}$ .
- 15.257** (a)  $0.1749 \text{ rad/s} \uparrow$ . (b)  $66.2 \text{ mm/s} \searrow 25^\circ$ .
- 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)  $3.43 \text{ N} \nearrow 20^\circ$ . (b)  $24.4 \text{ N} \searrow 73.4^\circ$ .
- 16.2**  $3.57 \text{ m/s}^2 \leftarrow$ .
- 16.3**  $6.84 \text{ ft/s}^2$ .
- 16.4** (a)  $13.42 \text{ ft/s}^2 \rightarrow$ . (b)  $8.67 \text{ lb}$ .
- 16.5** (a)  $25.8 \text{ ft/s}^2$ . (b)  $12.27 \text{ ft/s}^2$ . (c)  $13.32 \text{ ft/s}^2$ .
- 16.6** (a)  $36.8 \text{ ft}$ . (b)  $42.3 \text{ ft}$ .
- 16.7** (a)  $5.00 \text{ m/s}^2 \rightarrow$ . (b)  $0.311 \text{ m} \leq h \leq 1.489 \text{ m}$ .
- 16.8** (a)  $2.55 \text{ m/s}^2 \rightarrow$ . (b)  $h \leq 1.047 \text{ m}$ .
- 16.11** (a)  $0.337 \text{ g} \nearrow 30^\circ$ . (b)  $h/d = 4.00$ .
- 16.12** (a)  $0.252 \text{ g} \nearrow 30^\circ$ . (b)  $h/d = 4.00$ .
- 16.13**  $435 \text{ lb}$ .
- 16.14** (a)  $4.91 \text{ m/s}^2 \nearrow 30^\circ$ . (b)  $AD: 31.0 \text{ N}; BE: 11.43 \text{ N}$ .
- 16.16** (a)  $2.54 \text{ m/s}^2 \nearrow 15^\circ$ . (b)  $AC: 6.01 \text{ N}$  tension;  $BD: 22.4 \text{ N}$  tension.
- 16.17**  $CF: 4.05 \text{ lb}$  compression;  $BE: 14.33 \text{ lb}$  compression.
- 16.20** (a)  $30.6 \text{ ft/s}^2 \nwarrow 84.1^\circ$ . (b)  $\mathbf{B} = 1.285 \text{ lb} \nearrow 30^\circ, \mathbf{A} = 0.505 \text{ lb} \nearrow 30^\circ$ .
- 16.22**  $|V|_{\max} = 40.3 \text{ lb}, |M|_{\max} = 25.2 \text{ lb} \cdot \text{ft}$ .
- 16.25**  $87.8 \text{ lb} \cdot \text{ft}$ .
- 16.26**  $5230$  revolutions.
- 16.27**  $20.4 \text{ rad/s}^2 \downarrow$ .
- 16.28**  $32.7 \text{ rad/s}^2 \uparrow$ .
- 16.29**  $59.4 \text{ s}$ .
- 16.30**  $93.5$  revolutions.

- 16.34** (1): (a)  $8.00 \text{ rad/s}^2 \uparrow$ . (b)  $14.61 \text{ rad/s} \uparrow$ . (2): (a)  $6.74 \text{ rad/s}^2 \uparrow$ . (b)  $13.41 \text{ rad/s} \uparrow$ . (3): (a)  $4.24 \text{ rad/s}^2 \uparrow$ . (b)  $10.64 \text{ rad/s} \uparrow$ . (4): (a)  $5.83 \text{ rad/s}^2 \uparrow$ . (b)  $8.82 \text{ rad/s} \uparrow$ .
- 16.36** (a)  $7.63 \text{ rad/s}^2 \downarrow$ . (b)  $2.78 \text{ lb} \nearrow$ .
- 16.37** (a)  $1.255 \text{ ft/s}^2 \downarrow$ . (b)  $0.941 \text{ ft/s}^2 \uparrow$ .
- 16.38** (a)  $1.971 \text{ ft/s}^2 \uparrow$ . (b)  $1.971 \text{ ft/s}^2 \downarrow$ .
- 16.39** (a)  $\alpha_A = 12.50 \text{ rad/s}^2 \uparrow, \alpha_B = 33.3 \text{ rad/s}^2 \uparrow$ . (b)  $A: 320 \text{ rpm} \downarrow, B: 320 \text{ rpm} \uparrow$ .
- 16.40** (a)  $\alpha_A = 12.50 \text{ rad/s}^2 \uparrow, \alpha_B = 33.3 \text{ rad/s}^2 \uparrow$ . (b)  $A: 90.0 \text{ rpm} \uparrow, B: 120.0 \text{ rpm} \downarrow$ .
- 16.41** (a) Slipping occurs. (b)  $\alpha_A = 61.8 \text{ rad/s}^2 \uparrow, \alpha_B = 9.66 \text{ rad/s}^2 \downarrow$ .
- 16.42** (a) No slipping. (b)  $\alpha_A = 15.46 \text{ rad/s}^2 \uparrow, \alpha_B = 7.73 \text{ rad/s}^2 \downarrow$ .
- 16.48** (a)  $A: 18.40 \text{ ft/s}^2$ . (b)  $9.20 \text{ ft/s}^2 \leftarrow$ .
- 16.49** (a)  $12.00 \text{ in.}$  from A. (b)  $9.20 \text{ ft/s}^2 \rightarrow$ .
- 16.50** (a)  $2.50 \text{ m/s}^2 \rightarrow$ . (b)  $0$ .
- 16.51** (a)  $3.75 \text{ m/s}^2 \rightarrow$ . (b)  $1.25 \text{ m/s}^2 \leftarrow$ .
- 16.55**  $A: 0.885 \text{ m/s}^2 \downarrow, B: 2.60 \text{ m/s}^2 \uparrow$ .
- 16.56**  $A: 0.273 \text{ m/s}^2 \downarrow, B: 2.01 \text{ m/s}^2 \downarrow$ .
- 16.57**  $A: 359 \text{ lb}, B: 312 \text{ lb}$ .
- 16.58**  $A: 275 \text{ lb}, B: 361 \text{ lb}$ .
- 16.59** (a)  $0.741 \text{ rad/s}^2 \uparrow$ . (b)  $0.857 \text{ m/s}^2 \uparrow$ .
- 16.60** (a)  $2800 \text{ N}$ . (b)  $15.11 \text{ rad/s}^2 \downarrow$ .
- 16.63** (a)  $3.00 \text{ g/L} \downarrow$ . (b)  $1.000 \text{ g} \uparrow$ . (c)  $2.00 \text{ g} \downarrow$ .
- 16.64** (a)  $1.000 \text{ g/L} \downarrow$ . (b)  $0$ . (c)  $1.000 \text{ g} \downarrow$ .
- 16.65** (a)  $1.000 \text{ g/L} \downarrow$ . (b)  $0.866 \text{ g} \leftarrow$ . (c)  $1.323 \text{ g} \nearrow 49.1^\circ$ .
- 16.66** (a)  $0.500 \text{ g} \uparrow$ . (b)  $1.500 \text{ g} \downarrow$ .
- 16.67** (a)  $0$ . (b)  $1.000 \text{ g} \downarrow$ .
- 16.69** (a)  $1.597 \text{ s}$ . (b)  $9.86 \text{ ft/s}$ . (c)  $19.85 \text{ ft}$ .
- 16.70** (a)  $1.863 \text{ s}$ . (b)  $9.00 \text{ ft/s}$ . (c)  $22.4 \text{ ft}$ .
- 16.72** (a)  $v_0/r \uparrow$ . (b)  $v_0/\mu_k g$ . (c)  $v_0^2/2\mu_k g$ .
- 16.76** (a)  $12.08 \text{ rad/s}^2 \downarrow$ . (b)  $\mathbf{A}_x = 0.750 \text{ lb} \leftarrow, \mathbf{A}_y = 4.00 \text{ lb} \uparrow$ .
- 16.77** (a)  $24.0 \text{ in.}$  (b)  $8.05 \text{ rad/s}^2 \downarrow$ .
- 16.78** (a)  $107.1 \text{ rad/s}^2 \downarrow$ . (b)  $\mathbf{C}_x = 21.4 \text{ N} \leftarrow, \mathbf{C}_y = 39.2 \text{ N} \uparrow$ .
- 16.79** (a)  $150.0 \text{ mm}$ . (b)  $125.0 \text{ rad/s}^2 \downarrow$ .
- 16.81** (a)  $1529 \text{ kg}$ . (b)  $2.90 \text{ mm}$ .
- 16.82**  $13.64 \text{ kN} \rightarrow$ .
- 16.84** (a)  $1.500 \text{ g} \downarrow$ . (b)  $0.250 \text{ mg} \uparrow$ .
- 16.85** (a)  $1.286 \text{ g} \downarrow$ . (b)  $0.571 \text{ mg} \uparrow$ .
- 16.86** (a)  $2.50 \text{ g} \downarrow$ . (b)  $0.375 \text{ mg} \uparrow$ .
- 16.87**  $150.1 \text{ N} \nearrow 83.2^\circ$ .
- 16.88** (a)  $9.66 \text{ rad/s}^2 \uparrow$ . (b)  $5.43 \text{ lb} \cdot \text{ft} \uparrow$ .
- 16.89** (a)  $13.50 \text{ rad/s}^2 \uparrow$ . (b)  $6.79 \text{ N} \cdot \text{m} \uparrow$ .
- 16.95**  $2.55 \text{ ft}$ .
- 16.96**  $\tan \beta = \mu_s(1 + r^2/\bar{k}^2)$ .
- 16.97** (a)  $2.27 \text{ m}$  or  $7.46 \text{ ft}$ . (b)  $0.649 \text{ m}$  or  $2.13 \text{ ft}$ .
- 16.98** (a) rolls without sliding. (b)  $15.46 \text{ rad/s}^2 \downarrow, 10.30 \text{ ft/s}^2 \rightarrow$ .
- 16.99** (a) rolls without sliding. (b)  $23.2 \text{ rad/s}^2 \downarrow, 15.46 \text{ ft/s}^2 \rightarrow$ .
- 16.100** (a) slides. (b)  $4.29 \text{ rad/s}^2 \uparrow, 9.66 \text{ ft/s}^2 \rightarrow$ .
- 16.101** (a) slides. (b)  $12.88 \text{ rad/s}^2 \uparrow, 3.22 \text{ ft/s}^2 \leftarrow$ .
- 16.102** (a)  $17.78 \text{ rad/s}^2 \uparrow, 2.13 \text{ m/s}^2 \rightarrow$ . (b)  $0.122$ .
- 16.105** (a)  $8.89 \text{ rad/s}^2 \uparrow, 1.067 \text{ m/s}^2 \leftarrow$ . (b)  $0.165$ .
- 16.106** (a)  $0.556 \text{ g} \downarrow$ . (b)  $1.000 \text{ g} \downarrow$ . (c)  $0$ .
- 16.107** (a)  $1.125 \text{ g} \downarrow$ . (b)  $1.000 \text{ g} \downarrow$ . (c)  $1.333 \text{ g} \downarrow$ .
- 16.108** (a)  $0.765 \text{ g} \downarrow$ . (b)  $1.000 \text{ g} \downarrow$ . (c)  $0.667 \text{ g} \downarrow$ .
- 16.109** (a)  $5.57 \text{ ft/s}^2 \leftarrow$ . (b)  $0.779 \text{ lb} \leftarrow$ .

- 16.110** (a)  $64.4 \text{ rad/s}^2 \uparrow$ . (b)  $26.8 \text{ ft/s}^2 \downarrow$ .  
**16.111** (a)  $1.536 P/mr \downarrow$ . (b)  $0.884 P(mg + P)$ .  
**16.113** (a)  $0.1250 g/r \downarrow$ .  $0.1250 g \rightarrow$ ,  $0.1250 g \downarrow$ .  
**16.116**  $\mathbf{P} = 16.84 \text{ N} \swarrow 70.5$ ;  $\mathbf{M}_p = 0.228 \text{ N} \cdot \text{m} \downarrow$ .  
**16.117** (a)  $11.11 \text{ rad/s}^2 \downarrow$ . (b)  $37.7 \text{ N} \uparrow$ . (c)  $28.2 \text{ N} \rightarrow$ .  
**16.118** (a)  $97.8 \text{ N} \uparrow$ . (b)  $60.3 \text{ N} \uparrow$ .  
**16.119** (a)  $11.15 \text{ rad/s}^2 \uparrow$ . (b)  $1.155 \text{ lb} \leftarrow$ .  
**16.121** (a)  $12.04 \text{ rad/s}^2 \downarrow$ . (b)  $1.795 \text{ lb} \swarrow 20^\circ$ .  
**16.124**  $6.40 \text{ N} \leftarrow$ .  
**16.125**  $171.7 \text{ N} \rightarrow$ .  
**16.126**  $60.0 \text{ N} \rightarrow$ .  
**16.127**  $33.0 \text{ lb} \uparrow$ .  
**16.128**  $2.32 \text{ lb} \downarrow$ .  
**16.129**  $29.9 \text{ N} \swarrow 60^\circ$ .  
**16.130**  $23.5 \text{ N} \swarrow 60^\circ$ .  
**16.133**  $0.330 \text{ lb} \leftarrow$ .  
**16.134** (a)  $15.00 \text{ N} \cdot \text{m} \uparrow$ . (b)  $120.0 \text{ N} \rightarrow$ ,  $88.2 \text{ N} \uparrow$ .  
**16.135** (a)  $25.0 \text{ N} \cdot \text{m} \uparrow$ . (b)  $190.0 \text{ N} \rightarrow$ ,  $104.9 \text{ N} \uparrow$ .  
**16.136**  $\mathbf{A} = 1.565 \text{ lb} \uparrow$ ,  $\mathbf{B} = 1.689 \text{ lb} \uparrow$ .  
**16.138**  $\mathbf{B} = 805 \text{ N} \leftarrow$ ,  $\mathbf{D} = 426 \text{ N} \rightarrow$ .  
**16.139**  $\mathbf{B} = 525 \text{ N} \swarrow 38.1^\circ$ ,  $\mathbf{D} = 322 \text{ N} \swarrow 15.7^\circ$ .  
**16.140**  $(mv_0^2/6L) \tan \theta/\cos^3 \theta$ .  
**16.141** (a)  $9.36 \text{ m/s}^2 \swarrow 27.1^\circ$ . (b)  $278 \text{ N} \uparrow$ .  
**16.142** (a)  $9.10 \text{ m/s}^2 \swarrow 81.1^\circ$ . (b)  $6.54 \text{ N}$ .  
**16.143** (a)  $\mathbf{A}: 0.400 g/r \uparrow$ ;  $\mathbf{B}: 0.400 g/r \downarrow$ . (b)  $0.200 \text{ mg}$ .  
(c)  $0.800 g \downarrow$ .  
**16.144** (a)  $18.49 \text{ ft/s}^2 \swarrow 25^\circ$ . (b)  $8.38 \text{ rad/s}^2 \downarrow$ .  
**16.146** (a)  $13.55 \text{ m/s}^2 \downarrow$ . (b)  $2.34 \text{ m/s}^2 \downarrow$ .  
**16.147** (a)  $6.40 \text{ ft/s}^2 \rightarrow$ . (b)  $45.4 \text{ rad/s}^2 \uparrow$ .  
**16.151**  $10.39 \text{ lb} \cdot \text{in}$ . located  $20.8 \text{ in}$ . below  $\mathbf{A}$ .  
**16.153**  $27.2 \text{ rad/s}^2 \uparrow$ .  
**16.156**  $20.6 \text{ ft}$ .  
**16.157** (a)  $0.513 g/L \downarrow$ . (b)  $0.912 \text{ mg} \uparrow$ . (c)  $0.241 \text{ mg} \rightarrow$ .  
**16.159** (1): (a)  $1.200 g/c \downarrow$ . (b)  $0.671 \swarrow 63.4^\circ$ .  
(2): (a)  $1.412 g/c \downarrow$ . (b)  $0.706 g \downarrow$ .  
(3): (a)  $2.40 g/c \downarrow$ . (b)  $0.500 g \downarrow$ .  
**16.160** (a)  $0.333 g \uparrow$ . (b)  $1.667 g \downarrow$ .  
**16.161**  $23.7 \text{ rad/s}^2 \uparrow$ .  
**16.163** (a)  $51.2 \text{ rad/s}^2 \downarrow$ . (b)  $21.0 \text{ N} \uparrow$ .  
**16.164** (a)  $57.8 \text{ rad/s}^2 \downarrow$ . (b)  $20.4 \text{ N} \uparrow$ .

## CHAPTER 17

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

- 17.116**  $5.12^\circ$ .  
**17.117**  $55.9^\circ$ .  
**17.120** (a) 2.86 in. (b) 2.05 in.  
**17.121** (a)  $3.85 \text{ ft/s} \downarrow$ . (b)  $5.13 \text{ rad/s} \downarrow$ .  
**17.122** (a)  $0.256 \text{ ft/s}$ .  
**17.123**  $0.650\sqrt{gL} \rightarrow$ .  
**17.124**  $0.866\sqrt{gL} \rightarrow$ .  
**17.125** 725 mm.  
**17.126** 447 mm.  
**17.128** (a)  $2.60 \text{ rad/s} \downarrow$ . (b)  $1.635 \text{ m/s} \swarrow 53.4^\circ$ .  
**17.131** (a)  $\mathbf{v}_A = 0$ ,  $\boldsymbol{\omega}_A = v_1/r \downarrow$ ;  $\mathbf{v}_B = v_1 \rightarrow$ ;  $\boldsymbol{\omega}_B = 0$ .  
 (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**  $\boldsymbol{\omega}_{AB} = 2.65 \text{ rad/s} \downarrow$ ,  $\boldsymbol{\omega}_{BC} = 13.25 \text{ rad/s} \uparrow$ .  
**17.135**  $\mathbf{A} = 100.1 \text{ N} \uparrow$ ,  $\mathbf{B} = 43.9 \text{ N} \rightarrow$ .  
**17.136** (a) 118.7 rev. (b) 7.16 s.  
**17.138** (a)  $53.1^\circ$ . (b)  $1.095\sqrt{gL} \swarrow 53.1^\circ$ .  
**17.139**  $7.83 \text{ N} \rightarrow$ ,  $7.35 \text{ N} \uparrow$ .  
**17.141** (a)  $1.500 v_1/b \downarrow$ . (b)  $0.791 v_1 \searrow 18.4^\circ$ .  
**17.143** (a)  $4.81 \text{ rad/s} \downarrow$ . (b)  $6.81 \text{ rad/s} \downarrow$ .  
**17.145**  $0.400 r$   
**17.146** (a)  $1.286 \text{ rad/s} \uparrow$ . (b)  $0.719 \text{ lb} \rightarrow$ ,  $1.006 \text{ lb} \uparrow$ .

## CHAPTER 18

- 18.1**  $0.357 \text{ kg} \cdot \text{m}^2/\text{s}$ ;  $\theta_x = 48.6^\circ$ ,  $\theta_y = 41.4^\circ$ ,  $\theta_z = 90^\circ$ .  
**18.2**  $0.250 mr^2\omega_2 \mathbf{j} + 0.500 mr^2\omega_1 \mathbf{k}$ .  
**18.3**  $(ma^2\omega/12)(3 \mathbf{j} + 2 \mathbf{k})$ .  
**18.4**  $11.88^\circ$ .  
**18.7** (a)  $0.276 ma^2\omega$ . (b)  $25.2^\circ$ .  
**18.8** (a)  $0.432 ma^2\omega$ . (b)  $20.2^\circ$ .  
**18.9**  $-(1.747 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{i} + (3.59 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{j} + (0.0582 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{k}$ .  
**18.10**  $(1.848 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{i} - (0.455 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{j} + (1.118 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{k}$ .  
**18.11** (a)  $2.91 \text{ rad/s}$ . (b)  $0.0551 \text{ rad/s}$ .  
**18.12**  $(0.320 \text{ kg} \cdot \text{m}^2/\text{s})\mathbf{i} - (0.009 \text{ kg} \cdot \text{m}^2/\text{s})\mathbf{j} - (467 \text{ kg} \cdot \text{m}^2/\text{s})\mathbf{k}$ .  
**18.15** (a)  $mr^2\omega(0.379 \mathbf{i} - 0.483 \mathbf{j})$ . (b)  $51.9^\circ$ .  
**18.16** (a)  $(0.063 \text{ kg} \cdot \text{m}^2/\text{s})\mathbf{i} + (0.216 \text{ kg} \cdot \text{m}^2/\text{s})\mathbf{j}$ .  
 (b)  $-(0.513 \text{ kg} \cdot \text{m}^2/\text{s})\mathbf{i} + (0.216 \text{ kg} \cdot \text{m}^2/\text{s})\mathbf{j}$ .  
**18.19** (a)  $-(1.041 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{i} + (1.041 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{j} + (2.31 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{k}$ . (b)  $147.5^\circ$ .  
**18.20** (a)  $-(1.041 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{i} - (1.041 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{j} + (2.31 \text{ lb} \cdot \text{ft} \cdot \text{s})\mathbf{k}$ . (b)  $32.5^\circ$ .  
**18.21** 226 lb.  
**18.22** 2.66 s.  
**18.23** (a)  $-(0.300 \text{ m/s})\mathbf{k}$ . (b)  $-(0.962 \text{ rad/s})\mathbf{i} - (0.577 \text{ m/s})\mathbf{j}$ .  
**18.24** (a)  $(0.300 \text{ m/s})\mathbf{j}$ .  
 (b)  $-(3.46 \text{ rad/s})\mathbf{i} + (1.923 \text{ rad/s})\mathbf{j} - (0.857 \text{ rad/s})\mathbf{k}$ .  
**18.25** (a)  $(F\Delta t/m)\mathbf{i}$ . (b)  $(F\Delta t/ma)(-1.714 \mathbf{j} + 8.57 \mathbf{k})$ .  
**18.26** (a)  $(F\Delta t/m)\mathbf{i}$ . (b)  $(F\Delta t/ma)(3.43 \mathbf{j} - 5.14 \mathbf{k})$ .  
**18.29** (a)  $0.125 \omega_0(-\mathbf{i} + \mathbf{j})$ . (b)  $0.0884 a\omega_0 \mathbf{k}$ .  
**18.30** (a)  $0.1031 ma\omega_0 \mathbf{k}$ . (b)  $-0.01473 ma\omega_0 \mathbf{k}$ .  
**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**  $0.1250 mr^2(\omega_2^2 + 2\omega_1^2)$ .  
**18.41**  $0.1250 ma^2\omega^2$ .  
**18.42**  $0.228 mr^2\omega^2$ .  
**18.43**  $0.1896 mr^2\omega^2$ .  
**18.44** 1.296 J.  
**18.47**  $13.34 \text{ ft} \cdot \text{lb}$ .  
**18.48**  $12.67 \text{ ft} \cdot \text{lb}$ .  
**18.49**  $0.1250 ma^2\omega^2$ .  
**18.50**  $0.203 ma^2\omega^2$ .  
**18.53**  $16.75 \text{ ft} \cdot \text{lb}$ .  
**18.54**  $39.9 \text{ ft} \cdot \text{lb}$ .  
**18.55**  $(3.21 \text{ N} \cdot \text{m})\mathbf{k}$ .  
**18.56**  $0.500 mr^2\omega_1\omega_2 \mathbf{i}$ .  
**18.57**  $0.1667 ma^2\omega^2 \mathbf{i}$ .  
**18.58**  $-0.958 mr^2\omega^2 \mathbf{k}$ .  
**18.59**  $(2.91 \text{ lb} \cdot \text{ft})\mathbf{i}$ .  
**18.61**  $(1.890 \text{ N} \cdot \text{m})\mathbf{i} + (2.14 \text{ N} \cdot \text{m})\mathbf{j} + (3.21 \text{ N} \cdot \text{m})\mathbf{k}$ .  
**18.62**  $-(1.890 \text{ N} \cdot \text{m})\mathbf{i} - (2.14 \text{ N} \cdot \text{m})\mathbf{j} + (3.21 \text{ N} \cdot \text{m})\mathbf{k}$ .  
**18.65**  $\mathbf{A} = -(12.00 \text{ N})\mathbf{i}$ ,  $\mathbf{B} = -(4.00 \text{ N})\mathbf{j}$ .  
**18.66**  $\mathbf{C} = \frac{1}{6} mb\omega^2 \sin \beta \cos \beta \mathbf{i}$ ,  
 $\mathbf{D} = -\frac{1}{6} mb\omega^2 \sin \beta \cos \beta \mathbf{i}$ .  
**18.67**  $\mathbf{A} = (3.35 \text{ lb})\mathbf{k}$ ,  $\mathbf{B} = -(3.35 \text{ lb})\mathbf{k}$ .  
**18.68**  $\mathbf{A} = -(1.103 \text{ lb})\mathbf{j} - (0.920 \text{ lb})\mathbf{k}$ ,  
 $\mathbf{B} = (1.103 \text{ lb})\mathbf{j} + (0.920 \text{ lb})\mathbf{k}$ .  
**18.71** (a)  $(20.0 \text{ rad/s}^2)\mathbf{k}$ . (b)  $\mathbf{A} = -(3.75 \text{ N})\mathbf{k}$ ,  $\mathbf{B} = -(1.250 \text{ N})\mathbf{k}$ .  
**18.72** (a)  $(3 M_0/mb^2 \cos^2 \beta)\mathbf{j}$ .  
 (b)  $\mathbf{C} = (M_0 \tan \beta/2b)\mathbf{k}$ ,  $\mathbf{D} = -(M_0 \tan \beta/2b)\mathbf{k}$ .  
**18.75** (a)  $(2.33 \text{ lb} \cdot \text{ft})\mathbf{i}$ .  
 (b)  $\mathbf{A} = (0.466 \text{ lb})\mathbf{j}$ ,  $\mathbf{B} = -(0.466 \text{ lb})\mathbf{j}$ .  
**18.76** (a)  $(0.873 \text{ lb} \cdot \text{ft})\mathbf{i}$ .  
 (b)  $\mathbf{A} = -(0.218 \text{ lb})\mathbf{j} + (0.262 \text{ lb})\mathbf{k}$ ,  
 $\mathbf{B} = (0.218 \text{ lb})\mathbf{j} - (0.262 \text{ lb})\mathbf{k}$ .  
**18.77** (a)  $(0.1301 \text{ lb} \cdot \text{ft})\mathbf{i}$ . (b)  $\mathbf{A} = -(0.0331 \text{ lb})\mathbf{j} + (0.0331 \text{ lb})\mathbf{k}$ ,  
 $\mathbf{B} = (0.0331 \text{ lb})\mathbf{j} - (0.0331 \text{ lb})\mathbf{k}$ .  
**18.78**  $\mathbf{A} = -(0.444 \text{ lb})\mathbf{j} - (0.383 \text{ lb})\mathbf{k}$ ,  
 $\mathbf{B} = (0.444 \text{ lb})\mathbf{j} + (0.383 \text{ lb})\mathbf{k}$ .  
**18.79** (a)  $10.47 \text{ N} \cdot \text{m}$ . (b)  $10.47 \text{ N} \cdot \text{m}$ .  
**18.80**  $4.29 \text{ kN} \cdot \text{m}$ .  
**18.81**  $-(0.457 \text{ lb} \cdot \text{ft})\mathbf{i}$ .  
**18.83** 24.0 N.  
**18.84**  $1.138^\circ \downarrow$ . Point A moves up.  
**18.85** (a)  $38.1^\circ$ . (b)  $11.78 \text{ rad/s}$ .  
**18.86**  $13.46 \text{ rad/s}$ .  
**18.87** (a)  $53.6^\circ$ . (b)  $8.79 \text{ rad/s}$ .  
**18.88**  $\omega = 10 \cdot 20 \text{ rad/s}$ .  
**18.89**  $5.45 \text{ rad/s}$ .  
**18.90**  $2.11 \text{ N} \searrow 18.7^\circ$ .  
**18.93** (a)  $\mathbf{C} = -(123.4 \text{ N})\mathbf{i}$ ,  $\mathbf{D} = (123.4 \text{ N})\mathbf{i}$ .  
 (b)  $\mathbf{C} = \mathbf{D} = 0$ .  
**18.94** 91.2 rpm.  
**18.95**  $\mathbf{A} = (0.1906 \text{ lb})\mathbf{k}$ ,  $\mathbf{B} = -(0.1906 \text{ lb})\mathbf{k}$ .  
**18.96**  $7.87 \text{ rad/s}$ .  
**18.99**  $(11.23 \text{ N} \cdot \text{m}) \cos^2 \theta \mathbf{i} + (11.23 \text{ N} \cdot \text{m}) \sin \theta \cos \theta \mathbf{j} - (2.81 \text{ N} \cdot \text{m}) \sin \theta \cos \theta \mathbf{k}$ .  
**18.101**  $\mathbf{C} = -(89.8 \text{ N})\mathbf{i} + (52.8 \text{ N})\mathbf{k}$ ,  
 $\mathbf{D} = -(89.8 \text{ N})\mathbf{i} - (52.8 \text{ N})\mathbf{k}$ .  
**18.102** (a)  $(0.1962 \text{ N} \cdot \text{m})\mathbf{j}$ . (b)  $\mathbf{C} = -(48.6 \text{ N})\mathbf{i} + (38.9 \text{ N})\mathbf{k}$ ,  
 $\mathbf{D} = -(48.6 \text{ N})\mathbf{j} - (38.9 \text{ N})\mathbf{k}$ .  
**18.103** (a)  $-(5.39 \text{ lb} \cdot \text{ft})\mathbf{j}$ . (b)  $\mathbf{A} = -(11.65 \text{ lb})\mathbf{i} + (3.49 \text{ lb})\mathbf{k}$ ,  
 $\mathbf{M}_A = (5.53 \text{ lb} \cdot \text{ft})\mathbf{i} + (8.73 \text{ lb} \cdot \text{ft})\mathbf{k}$ .  
**18.104** (a)  $(1.382 \text{ lb} \cdot \text{ft})\mathbf{i}$ . (b)  $\mathbf{D} = -(6.70 \text{ lb})\mathbf{j} + (4.89 \text{ lb})\mathbf{k}$ ,  
 $\mathbf{E} = -(1.403 \text{ lb})\mathbf{j} + (4.89 \text{ lb})\mathbf{k}$ .  
**18.107** 299 rpm.  
**18.108**  $55.3^\circ$ .



- 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)  $\theta_x = 52.5^\circ$ ,  $\theta_y = 37.5^\circ$ ,  $\theta_z = 90^\circ$ .  
 (b) 53.8 rev/h. (c) 6.68 rev/h.  
**18.126** (a)  $\theta_x = 90^\circ$ ,  $\theta_y = 17.65^\circ$ ,  $\theta_z = 72.35^\circ$ .  
 (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;  $\gamma_x = 90^\circ$ ,  $\gamma_y = 100.05^\circ$ ,  $\gamma_z = 10.05^\circ$ .  
 (b)  $\theta_x = 90^\circ$ ,  $\theta_y = 113.9^\circ$ ,  $\theta_z = 23.9^\circ$ .  
 (c) precession: 47.1 rpm; spin: 64.6 rpm.  
**18.131** (a) 4.00 rad/s. (b) 5.66 rad/s.  
**18.132** (a)  $\theta_0 \leq \theta \leq 180^\circ - \theta_0$ .  
 (b)  $\dot{\theta}_{\max} = \dot{\phi}_0 \sin \theta_0 \cos \theta_0$ . (c)  $\dot{\phi}_{\min} = \dot{\phi}_0 \sin^2 \theta_0$ .  
**18.133** (a)  $30^\circ \leq \theta \leq 150^\circ$ . (b)  $\dot{\phi}_{\min} = 2.40$  rad/s.  
 (c)  $\dot{\theta}_{\max} = 3.29$  rad/s.  
**18.134** (a)  $\dot{\phi}_{\min} = 1.200$  rad/s. (b)  $\dot{\theta}_{\max} = 2.68$  rad/s.  
**18.137** (a) 44.1°. (b)  $\dot{\phi} = -8.72$  rad/s,  $\dot{\psi} = 56.3$  rad/s.  
**18.138** (a) 32.7 rad/s. (b)  $\dot{\phi} = -13.33$  rad/s,  $\dot{\psi} = 44.3$  rad/s.  
**18.140** (a)  $\frac{1}{2}I(\dot{\phi} \sin \theta)^2 + \frac{1}{2}I\dot{\theta}^2 + \frac{1}{2}I\omega_z^2 + mge \cos \theta = E$ .  
**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)  $\frac{1}{6}\omega_0a\mathbf{k}$ .  
**18.151**  $\frac{5}{48}ma^2\omega_0^2$ .  
**18.153** (a) 52.1 rad/s<sup>2</sup>. (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.

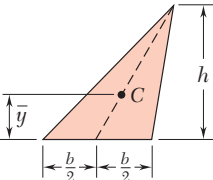
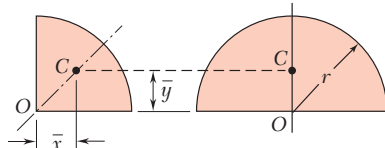
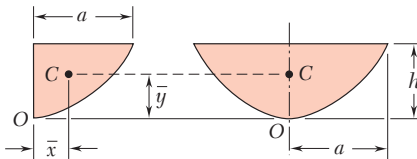
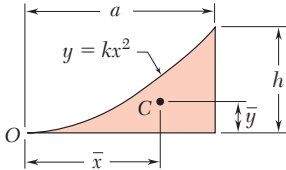
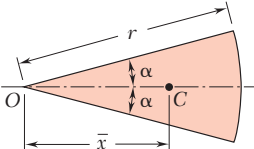
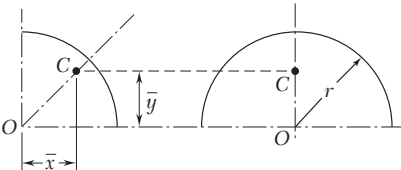
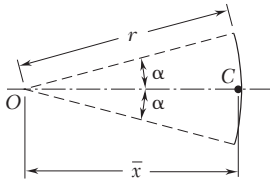
## CHAPTER 19

- 19.1** 1.047 ft/s, 65.8 ft/s<sup>2</sup>.  
**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<sup>2</sup>.  
**19.5** (a) 0.324 s, 3.08 Hz. (b) 12.91 mm, 484 m/s<sup>2</sup>.  
**19.6** (a) 10.75°. (b) 6.04 ft/s<sup>2</sup>.  
**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<sup>2</sup> ↓.  
**19.12** (a) 0.0352 s. (b) 6.34 ft/s ↑, 64.9 ft/s<sup>2</sup> ↓.  
**19.13** 0.445 ft ↑, 2.27 ft/s ↓, 114.7 ft/s<sup>2</sup> ↓.  
**19.14** (a) 3.89°. (b) 0.1538 m/s, 0.666 m/s<sup>2</sup>.  
**19.17** (a) 0.208 s, 4.81 Hz. (b) 1.361 m/s, 41.1 m/s<sup>2</sup>.  
**19.18** (a) 0.416 s, 2.41 Hz. (b) 0.680 m/s, 10.29 m/s<sup>2</sup>.  
**19.19** (a) 0.361 s, 2.77 Hz. (b) 2.54 ft/s, 441 ft/s<sup>2</sup>.  
**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<sup>2</sup>.  
**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**  $4.86 \text{ lb} \cdot \text{ft} \cdot \text{s}^2$ .  
**19.69**  $2\pi\sqrt{l/g}$ .  
**19.70** 3.18 s.  
**19.71** 1.476 m/s, 31.1 m/s<sup>2</sup>.  
**19.72** 1.379 in., 888 in./s<sup>2</sup>.  
**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**  $\omega_f \leq 322$  rpm and  $\omega_f \geq 329$  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)  $\ddot{\theta} + (3c/m)\dot{\theta} + (3k/4m)\theta = 0$ . (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)  $m \frac{d^2x}{dt^2} + c \frac{dx}{dt} + kx = \delta_m(k \sin \omega_f t + c\omega_f \cos \omega_f t)$   
 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)  $kx_A + c \frac{d}{dt}(x_A - x_m) = 0$ ,  
 $m \frac{d^2x_m}{dt^2} + c \frac{d}{dt}(x_m - x_A) = P_m \sin \omega_f t$ .  
 (b)  $\frac{1}{C}q_A + R \frac{d}{dt}(q_A - q_m) = 0$ ,  
 $L \frac{d^2q_m}{dt^2} + R \frac{d}{dt}(q_m - q_A) = E_m \sin \omega_f t$ .  
**19.158** (a)  $m \frac{d^2x_m}{dt^2} + k_2(x_m - x_A) = P_m \sin \omega_f t$ .  
 $C \frac{dx_A}{dt} + k_1x_A + k_2(x_A + x_m) = 0$   
 (b)  $L \frac{d^2q_m}{dt^2} + \frac{1}{C_2}(q_m - q_A) = E_m \sin \omega_f t$   
 $R \frac{dq_A}{dt} + \frac{1}{C_1}q_A + \frac{1}{C_2}(q_A - q_m) = 0$   
**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	$\alpha r^2$
Quarter-circular arc		$\frac{2r}{\pi}$	$\frac{2r}{\pi}$	$\frac{\pi r}{2}$
Semicircular arc		0	$\frac{2r}{\pi}$	$\pi r$
Arc of circle		$\frac{r \sin \alpha}{\alpha}$	0	$2\alpha r$

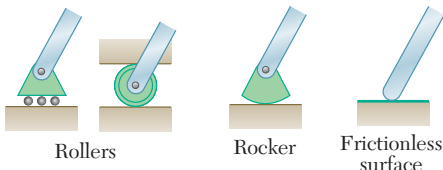
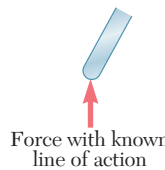
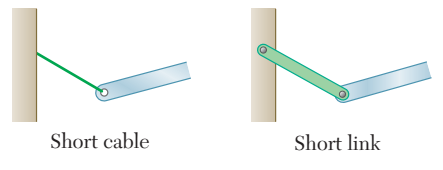
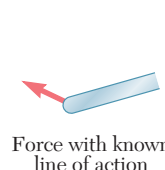
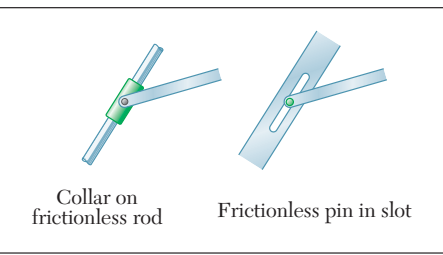
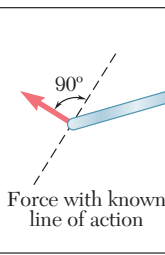
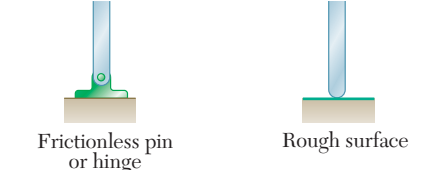
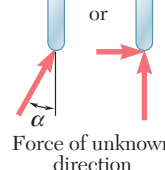
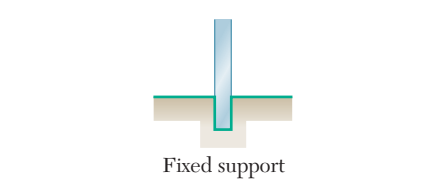
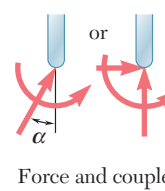
## Moments of Inertia of Common Geometric Shapes

<p>Rectangle</p> $\bar{I}_{x'} = \frac{1}{12}bh^3$ $\bar{I}_{y'} = \frac{1}{12}b^3h$ $I_x = \frac{1}{3}bh^3$ $I_y = \frac{1}{3}b^3h$ $J_C = \frac{1}{12}bh(b^2 + h^2)$	
<p>Triangle</p> $\bar{I}_{x'} = \frac{1}{36}bh^3$ $I_x = \frac{1}{12}bh^3$	
<p>Circle</p> $\bar{I}_x = \bar{I}_y = \frac{1}{4}\pi r^4$ $J_O = \frac{1}{2}\pi r^4$	
<p>Semicircle</p> $I_x = I_y = \frac{1}{8}\pi r^4$ $J_O = \frac{1}{4}\pi r^4$	
<p>Quarter circle</p> $I_x = I_y = \frac{1}{16}\pi r^4$ $J_O = \frac{1}{8}\pi r^4$	
<p>Ellipse</p> $\bar{I}_x = \frac{1}{4}\pi ab^3$ $\bar{I}_y = \frac{1}{4}\pi a^3b$ $J_O = \frac{1}{4}\pi ab(a^2 + b^2)$	

## Mass Moments of Inertia of Common Geometric Shapes

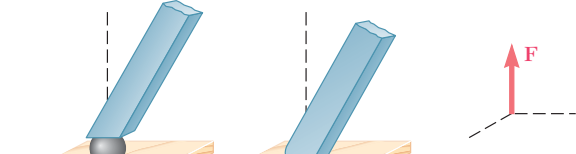

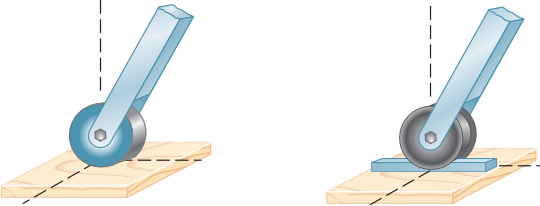
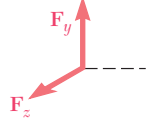
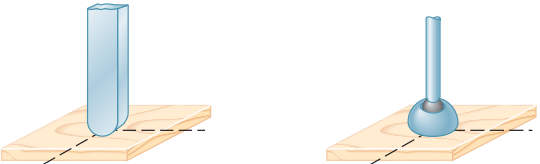
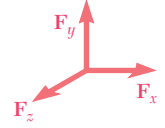
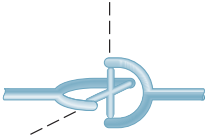
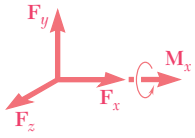
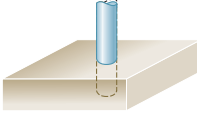
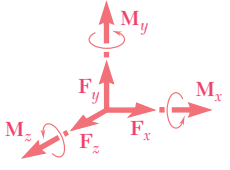
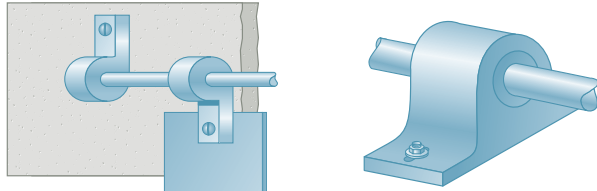
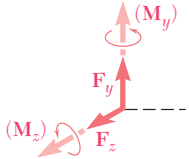
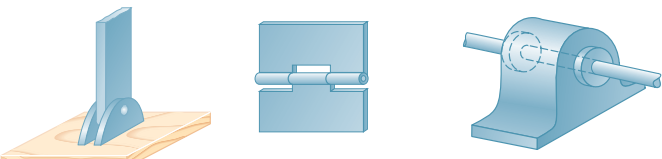
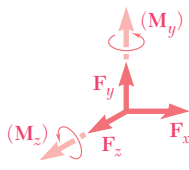
<p>Slender rod</p> $I_y = I_z = \frac{1}{12}mL^2$	
<p>Thin rectangular plate</p> $I_x = \frac{1}{12}m(b^2 + c^2)$ $I_y = \frac{1}{12}mc^2$ $I_z = \frac{1}{12}mb^2$	
<p>Rectangular prism</p> $I_x = \frac{1}{12}m(b^2 + c^2)$ $I_y = \frac{1}{12}m(c^2 + a^2)$ $I_z = \frac{1}{12}m(a^2 + b^2)$	
<p>Thin disk</p> $I_x = \frac{1}{2}mr^2$ $I_y = I_z = \frac{1}{4}mr^2$	
<p>Circular cylinder</p> $I_x = \frac{1}{2}ma^2$ $I_y = I_z = \frac{1}{12}m(3a^2 + L^2)$	
<p>Circular cone</p> $I_x = \frac{3}{10}ma^2$ $I_y = I_z = \frac{3}{5}m(\frac{1}{4}a^2 + h^2)$	
<p>Sphere</p> $I_x = I_y = I_z = \frac{2}{5}ma^2$	

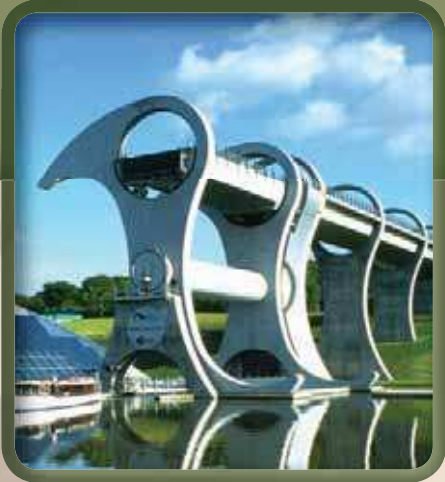
## Reactions at Supports and Connections for a Two-Dimensional Structure

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

The first step in the solution of an equilibrium problem concerning the equilibrium of a rigid body is to construct a free-body diagram of the body. To do this, it is necessary to show on the diagram the reactions (roughly with the ground and other bodies) of the possible motion of the body. The figures on this page summarize the possible reactions exerted on two- and three-dimensional bodies.

## Reactions at Supports and Connections for a Three-Dimensional Structure

 <p>Ball      Frictionless surface</p> <p>Force with known line of action (one unknown)</p>	 <p>Cable</p> <p>Force with known line of action (one unknown)</p>
 <p>Roller on rough surface      Wheel on rail</p>	 <p>Two force components</p>
 <p>Rough surface      Ball and socket</p>	 <p>Three force components</p>
 <p>Universal joint</p>	 <p>Three force components and one couple</p>  <p>Fixed support</p>  <p>Three force components and three couples</p>
 <p>Hinge and bearing supporting radial load only</p>	 <p>Two force components (and two couples; see page 191)</p>
 <p>Pin and bracket      Hinge and bearing supporting axial thrust and radial load</p>	 <p>Three force components (and two couples; see page 191)</p>



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