

参考答案

第 1 章

- 1-1 (1) $F_x=4$, $F_y=6$, $F_z=3$; (2) $F_x=4(\text{N})$, $F_y=6(\text{N})$, $F_z=3(\text{N})$; (3) $F=7.81(\text{N})$;
(4) $\cos(\boldsymbol{F}, \boldsymbol{i})=0.5122$; $\cos(\boldsymbol{F}, \boldsymbol{j})=0.7682$; $\cos(\boldsymbol{F}, \boldsymbol{k})=0.3841$
- 1-2 $F_{1x}=86.6(\text{N})$, $F_{1y}=50(\text{N})$; $F_{2x}=30(\text{N})$, $F_{2y}=-40(\text{N})$; $F_{3x}=0$, $F_{3y}=60(\text{N})$; $F_{4x}=-56.6(\text{N})$,
 $F_{4y}=56.6(\text{N})$
- 1-3 $F_{1x}=-1.2(\text{kN})$, $F_{1y}=1.6(\text{kN})$, $F_{1z}=0$; $F_{2x}=0.424(\text{kN})$, $F_{2y}=0.566(\text{kN})$,
 $F_{2z}=0.707(\text{kN})$; $F_{3x}=F_{3y}=0$, $F_{3z}=3(\text{kN})$
- 1-4 $F_R=161.2(\text{N})$, $\angle(F_R, F_1)=29^\circ 44'$
- 1-5 $F_R=669.5(\text{N})$, $\angle(F_R, x)=-34^\circ 52'$
- 1-6 0; $\sqrt{3}FL$
- 1-7 $2F$; $2Fa$
- 1-8 略
- 1-9 略

第 2 章

- 2-1 (a) $15 \text{ kN} \cdot \text{m}$; (b) $105 \text{ kN} \cdot \text{m}$
- 2-2 $32.42 \text{ N} \cdot \text{m}$ (顺转), 力线 $\perp AB$
- 2-3 $F_R=4\sqrt{2}(\text{N})$, 方向与 x 轴正向成 45° 角, 合力作用线过 A 点
- 2-4 力偶, $M=\frac{\sqrt{3}}{2}FL$, 逆转
- 2-5 $F_R=709.4(\text{kN})$, $\cos(\boldsymbol{F}_R, \boldsymbol{i})=0.3283$, $\cos(\boldsymbol{F}_R, \boldsymbol{j})=-0.9446$, $x=3.514(\text{m})$
合力作用线方程: $670.1x+232.9y-2355=0$
- 2-6 (a) $2F$, 方向: 由 B 指向 A ; (c) $\sqrt{3}F$, 方向: 竖直向下;
(b) F , 方向: 与水平线夹角 60° 斜向下。
- 2-7 $F_A=2010(\text{N})$, $F_C=2000(\text{N})$
- 2-8 $F_D=\frac{F}{2}$ ($\uparrow$), $F_A=\frac{\sqrt{5}}{2}F$ ($\swarrow$)

$$2-9 \quad \text{I} = \frac{b}{3}, \text{II} = \frac{b}{4}, \text{III} = \frac{b}{5}, \text{IV} = \frac{b}{6}$$

$$2-10 \quad F = P = 9(\text{kN}), F_{\text{NA}} = F_{\text{ND}} = 11.7(\text{kN})$$

$$2-11 \quad F_A = F_B = \frac{\sqrt{3}}{3}P$$

$$2-12 \quad F_A = \frac{M}{2\sqrt{2}a} \quad (\searrow), F_C = \frac{M}{2\sqrt{2}a} \quad (\swarrow)$$

$$2-13 \quad (\text{a}) F_{Ax} = F_{Bx} = F, F_{Ay} = -\frac{F}{2}, F_{By} = F_C = \frac{F}{2}, M_A = -\frac{\sqrt{2}}{4}Fl;$$

$$(\text{b}) F_{Ax} = 0, F_{Ay} = F_B = F_C = \sqrt{2}\frac{M}{l}, M_A = -2M;$$

$$2-14 \quad (\text{a}) F_A = F_B = F_C = \frac{\sqrt{2}}{2} \frac{M}{a}; (\text{b}) F_A(\nearrow) = F_C(\swarrow) = \frac{\sqrt{2}}{4}F, F_B = \frac{\sqrt{10}}{4}F(\searrow)$$

$$2-15 \quad F_{\text{NA}} = F_{Bx} = \frac{P_1 a P_2 b}{c}, F_{By} = P_1 + P_2$$

$$2-16 \quad F_{\text{NA1}} = 29.67(\text{N}), F_{\text{NA2}} = 17.5(\text{N}), F_{\text{NB}} = 18.42(\text{N}), F_{\text{AB}} = 6.7(\text{N})$$

$$2-17 \quad F_H = \frac{F}{2 \sin^2 \theta}$$

$$2-18 \quad \frac{F_1}{F_2} = 0.6124$$

$$2-19 \quad F = \frac{M}{a} \cot 2\theta$$

$$2-20 \quad F_{Ax} = 0, F_{Ay} = -250(\text{N}), F_B = 3750(\text{N})$$

$$2-21 \quad F_{\text{RA}} = 2 \cos \frac{\theta}{2}, M_A = Gb(1 + \cos \theta) \quad (\text{逆转})$$

$$2-22 \quad F_A = \frac{20}{\sqrt{3}}(\text{kN}), F_B = \frac{20}{\sqrt{3}}(\text{kN}), F_{EC} = 10\sqrt{2}(\text{kN})$$

$$2-23 \quad P_2 = 333.3(\text{kN}), x = 6.75(\text{m})$$

$$2-24 \quad F_A = -48.33(\text{kN}), F_B = 100(\text{kN}), F_D = 8.33(\text{kN})$$

$$2-25 \quad F_{Ax} = 4.661(\text{kN}), F_{Ay} = 47.62(\text{kN}), F_{BC} = 22.4(\text{kN})$$

$$2-26 \quad Q \geq \frac{R}{a} P \tan \alpha \tan \frac{90^\circ - \alpha}{2}$$

$$2-27 \quad M = \frac{Fr}{\sin \beta} \cos(\beta - \theta)$$

$$2-28 \quad M = \frac{r_1}{r_2} Pr$$

$$2-29 \quad (\text{a}) F_{Ax} = 0, F_{Ay} = qa, M_A = \frac{1}{2}qa^2, F_{Bx} = F_{By} = 0, F_C = 0;$$

- (b) $F_{Ax} = \frac{qa}{2} \tan \alpha$, $F_{Ay} = \frac{1}{2}qa$, $M_A = \frac{1}{2}qa^2$, $F_{Bx} = \frac{qa}{2} \tan \alpha$, $F_{By} = \frac{1}{2}qa$, $F_C = \frac{qa}{2\cos \alpha}$;
- (c) $F_{Ax} = \frac{M}{a} \tan \alpha$, $F_{Ay} = -\frac{M}{a}$, $M_A = -M$, $F_B = F_C = \frac{M}{a\cos \alpha}$;
- (d) $F_{Ax} = F_{Ay} = 0$, $M_A = M$, $F_{Bx} = F_{By} = F_C = 0$;
- (e) $F_{Ax} = \frac{qa}{8} \tan \alpha$, $F_{Ay} = \frac{7}{8}qa$, $M_A = \frac{3}{4}qa^2$, $F_{Bx} = \frac{qa}{8} \tan \alpha$, $F_{By} = \frac{3}{8}qa$, $F_C = \frac{qa}{8\cos \alpha}$
- 2-30 $F_{Ax} = 1200(\text{N})$, $F_{Ay} = 150(\text{N})$, $F_B = 1050(\text{N})$, $F_{BC} = 1500(\text{N})$
- 2-31 $F_{Ax} = F_{Cx} = 0.4(\text{kN})$, $F_{Ay} = \frac{64}{15}(\text{kN})$, $M_A = -\frac{22}{15}(\text{kN} \cdot \text{m})$, $F_B = \frac{86}{15}(\text{kN})$, $F_{Cy} = -\frac{86}{15}(\text{kN})$
- 2-32 $F_{Ax} = 40(\text{kN})$, $F_{Ay} = 113.3(\text{kN})$, $M_A = 575.8(\text{kN} \cdot \text{m})$, $F_C = -44(\text{kN})$
- 2-33 $F_{Ax} = -66.36(\text{N})$, $F_{Ay} = 120.47(\text{N})$, $F_{Bx} = 36.36(\text{N})$, $F_{By} = 86.13(\text{N})$
- 2-34 $F_{CD} = -\frac{P_1}{3} - \frac{P_2}{2}$
- 2-35 $F_E = \sqrt{2}F$, $F_{Ax} = F - 6qa$, $F_{Ay} = 2F$, $M_A = 5Fa + 18qa^2$
- 2-36 $F_{Ax} = -F/2$, $F_{Ay} = -F$, $F_{Bx} = -F/2$, $F_{By} = 2F$
- 2-37 $S_1 = 2P(\text{拉})$, $S_2 = S_6 = 2.24P(\text{压})$, $S_3 = P(\text{拉})$, $S_4 = 2P(\text{压})$, $S_5 = 0$
- 2-38 $S_1 = 1.08P(\text{压})$, $S_2 = 0.93P(\text{拉})$, $S_3 = 0$, $S_4 = 1.08P(\text{压})$,
 $S_5 = 0.50P(\text{拉})$, $S_6 = 0.075P(\text{拉})$, $S_7 = P(\text{压})$, $S_8 = 0.81P(\text{拉})$, $S_9 = 0.93P(\text{压})$
- 2-39 $S_1 = 2.60P(\text{压})$, $S_2 = 0.43P(\text{拉})$, $S_3 = 2.38P(\text{拉})$
- 2-40 $S_1 = 1.66P(\text{压})$, $S_2 = 1.33P(\text{拉})$, $S_3 = \frac{2}{3}\sqrt{13}P(\text{压})$, $S_4 = 0$, $S_5 = 1.5P(\text{拉})$,
 $S_6 = 1.5\sqrt{5}P(\text{压})$, $S_7 = 0$
- 2-41 $S_{AB} = 0.43P(\text{拉})$

第3章

- 3-1 (1) $\mathbf{M}_A(\mathbf{F}) = -2\mathbf{i} + \mathbf{j} + \mathbf{k}(\text{N} \cdot \text{m})$; (2) $\mathbf{M}_{B'}(\mathbf{F}) = 10\mathbf{i} - 8\mathbf{k}(\text{N} \cdot \text{m})$;
 (3) $M_x(\mathbf{F}) = -2(\text{N} \cdot \text{m})$, $M_y(\mathbf{F}) = 1(\text{N} \cdot \text{m})$, $M_z(\mathbf{F}) = 1(\text{N} \cdot \text{m})$
- 3-2 $\mathbf{M}_O = -F_z a \mathbf{i} - F_z b \mathbf{j} + (F_y b - F_x a) \mathbf{k}$; $M_z = F_y b - F_x a$
- 3-3 $M_x(\mathbf{F}) = \frac{F}{4}(h - 3r)$, $M_y(\mathbf{F}) = \frac{\sqrt{3}}{4}F(r + h)$, $M_z(\mathbf{F}) = -\frac{Fr}{2}$
- 3-4 $M_z(\mathbf{F}) = -101.4(\text{N} \cdot \text{m})$
- 3-5 $1.66M$
- 3-6 (1) $\mathbf{F}'_R = 400\mathbf{j}(\text{N})$, $\mathbf{M}_O = -60\mathbf{i} + 15\mathbf{j} + 66\mathbf{k}(\text{N} \cdot \text{m})$; (2) 力螺旋
- 3-7 $\mathbf{F}'_R = -143.9\mathbf{i} + 1011\mathbf{j} - 516.9\mathbf{k}(\text{N})$, $\mathbf{M}_O = -48\mathbf{i} + 21.07\mathbf{j} - 19.4\mathbf{k}(\text{N} \cdot \text{m})$
- 3-8 $F_R = 30\sqrt{2}(\text{N})$, 与 x 、 z 轴的夹角都为 45° , 与 y 轴的夹角为 90° , 作用线过点
 $\left(-\frac{4}{3}, \frac{2}{3}, 0\right)$
- 3-9 $F_{TA} = 106(\text{N})$, $F_{TB} = 53(\text{N})$, $F_{TC} = 91.8(\text{N})$

$$3-10 \quad F_1 = -5(\text{kN})(\text{压}), F_2 = -5(\text{kN})(\text{压}), F_3 = -7.07(\text{kN})(\text{压}),$$

$$F_4 = 5(\text{kN})(\text{拉}), F_5 = 5(\text{kN})(\text{拉}), F_6 = -10(\text{kN})(\text{压})$$

$$3-11 \quad F = 50(\text{N}), \alpha = 143^\circ 8'$$

$$3-12 \quad l = 0.1(\text{m}), F_{Ax} = F_{Bx} = 0, F_{Az} = 300(\text{N}), F_{Bz} = 950(\text{N})$$

$$3-13 \quad F = 70.9(\text{N}), F_{Ax} = -68.4(\text{N}), F_{Ay} = -47.6(\text{N}), F_{Bx} = -207(\text{N}), F_{By} = -19.04(\text{N})$$

$$3-14 \quad F_1 = 750(\text{N}), F_2 = 250\sqrt{2}(\text{N}), F_3 = 0$$

$$3-15 \quad F_1 = 0, F_2 = -\sqrt{2}F(\text{压}), F_3 = 0, F_4 = \sqrt{3}F(\text{拉}), F_5 = 0, F_6 = 0$$

$$3-16 \quad x_C = 135(\text{mm}), y_C = 140(\text{mm})$$

$$3-17 \quad (\text{a}) x_C = 0, y_C = 105(\text{mm}); (\text{b}) x_C = 17.5(\text{mm}), y_C = 0; (\text{c}) x_C = 0, y_C = 621.4(\text{mm})$$

$$3-18 \quad C(0.511, 1.41, 0.717)$$

$$3-19 \quad h = \frac{r}{\sqrt{2}}$$

第4章

$$4-1 \quad F = 15(\text{N})(\rightarrow)$$

$$4-2 \quad \text{向左时}, P = 250(\text{N}); \text{向右时}, P = 204.5(\text{N})$$

$$4-3 \quad f = 0.8$$

$$4-4 \quad f = 0.224$$

$$4-5 \quad R = 31.6(\text{mm})$$

$$4-6 \quad \text{距 } A \text{ 端为: } l\sin(60^\circ - \varphi)\cos(30^\circ + \varphi), \text{ 距 } B \text{ 端为: } l\sin(30^\circ - \varphi)\cos(60^\circ + \varphi);$$

$$\text{或距 } B \text{ 端为: } l\sin(30^\circ + \varphi)\cos(60^\circ - \varphi), \text{ 距 } A \text{ 端为: } l\sin(60^\circ + \varphi)\cos(30^\circ - \varphi)$$

$$4-7 \quad x_{\max} = \frac{1}{2} \left(\frac{b}{\tan \varphi} \right)$$

$$4-8 \quad P_{\min} = 280(\text{N})$$

$$4-9 \quad e \leqslant fr$$

$$4-10 \quad (1) A \text{ 轮不转}, P_{\min} = 107(\text{N}); (2) B \text{ 轮不转}, P_{\min} = 250(\text{N})$$

$$(3) \text{ 两轮均不转}, P_{\min} = 300(\text{N});$$

立柜不翻倒条件:

两轮均不转为 $h \leqslant a/2f$; B 轮不转为 $h \leqslant a/2f$; A 轮不转, 立柜不会翻倒。

$$4-11 \quad b_{\max} = 11(\text{cm})$$

$$4-12 \quad \text{当 } \tan \alpha > f \text{ 时}, \frac{\alpha Q}{b(f \cos \alpha + \sin \alpha)} \leqslant P \leqslant \frac{\alpha Q}{b(\sin \alpha - f \cos \alpha)}$$

$$\text{当 } \tan \alpha > f \text{ 时}, P \geqslant \frac{\alpha Q}{b(\sin \alpha + f \cos \alpha)}$$

$$4-13 \quad P_{\min} = 720(\text{N})$$

$$4-14 \quad M = Q(R \sin \alpha - r), F = Q \sin \alpha, N = P - Q \cos \alpha$$

$$4-15 \quad (1) T_{\max} = 2.41(\text{N}); (2) M = 0.012(\text{N} \cdot \text{m}), F = 2.21(\text{N})(\rightarrow)$$

第 5 章

$$5-2 \quad \frac{(x-a)^2}{(b+l)^2} + \frac{y^2}{l^2} = 1$$

$$5-3 \quad x_B = r \cos \omega t + l \sqrt{1 - \left(\frac{r}{l}\right)^2 \sin^2 \omega t}, \quad y_C = r \sin \omega t + l \sqrt{1 - \left(\frac{r}{l}\right)^2 \cos^2 \omega t}$$

$$5-4 \quad r = b + 2c \cos \omega t, \quad \varphi = \omega t, \quad r = b + 2c \cos \varphi \text{ 螺旋线}$$

$$5-5 \quad x^2 y^2 = (a-y)^2 (a^2 - y^2), \quad v = \sqrt{v_x^2 + v_y^2} = v_0 \sqrt{1 - 2 \sin^3 \varphi + \sin^4 \varphi}$$

$$5-6 \quad t = 0.21(\text{s}), \quad a_B = 34.6(\text{m/s}^2)$$

$$5-7 \quad s = b \tan^{-1} \frac{ut}{l} \varphi = \frac{\pi}{4} v_C = bu/21$$

$$5-8 \quad a_B = 5.37(\text{m/s}^2), \quad \angle(a_B, n) = 12.25^\circ$$

$$5-11 \quad \varphi = \arctan \frac{v_0 t}{b} (\text{rad}), \quad \omega = \frac{bv_0}{b^2 + v_0^2 t^2} (\text{rad/s}), \quad \alpha = -\frac{2bv_0^3 t}{(b^2 + v_0^2 t^2)^2} (\text{rad/s}^2)$$

$$5-12 \quad \varphi_1 = \arctan \frac{r \sin \omega t}{a + r \cos \omega t}, \quad \omega_1 = \frac{r(a \cos \omega t + r)}{a^2 + r^2 + 2ar \cos \omega t} \omega$$

$$5-13 \quad v_A = 0.86(\text{m/s})$$

$$5-14 \quad v_O = 0.707(\text{m/s}), \quad a_O = 3.33(\text{m/s}^2)$$

$$5-15 \quad a_B = 1.2(\text{m/s}^2), \quad \omega = 1.7(3\text{rad/s}), \quad \alpha = 5.2(\text{rad/s}^2)$$

$$5-16 \quad x' = v_e t, \quad y' = a \cos(kt + \beta); \quad y' = a \cos\left(k \frac{x'}{v_e} + \beta\right)$$

$$5-17 \quad v_M = \frac{1}{\sin \alpha} \sqrt{v_1^2 + v_2^2 - 2v_1 v_2 \cos \alpha}$$

$$5-18 \quad y = 2\pi R \frac{Z_1}{Z_2} t^2, \quad v = 4\pi R \frac{Z_1}{Z_2} t, \quad a = 4\pi R \frac{Z_1}{Z_2}$$

$$5-19 \quad \alpha_2 = 5000\pi(100 - 5t)^{-2} (\text{rad/s}^2), \quad a_B = 300\pi \sqrt{(200\pi)^2 + 1} (\text{mm/s})^2 = 592.2(\text{m/s}^2)$$

$$5-20 \quad \alpha = \frac{bv^2}{2\pi r^3}$$

第 6 章

$$6-1 \quad v_r = 33.5(\text{m/s})$$

$$6-2 \quad v = v_e = 0.4(\text{m/s})$$

$$6-3 \quad \omega_2 = 1.5(\text{rad/s}), \quad \omega_2 = 2(\text{rad/s})$$

$$6-4 \quad v_{Mx} = 0.52(\text{m/s}), \quad v_{My} = -1.86(\text{m/s})$$

$$6-5 \quad v_r = 3.98(\text{m/s}); \text{ 当 } v_B = 1.04 \text{ m/s 时, } v_r \text{ 与传送带 } B \text{ 相垂直。}$$

$$6-6 \quad \omega_D = 2.67(\text{rad/s})$$

$$6-7 \quad v_A = \frac{blv}{x^2 + b^2} (\perp OA)$$

$$6-8 \quad v_a = 11.2 (\text{m/s})$$

$$6-9 \quad v_M = \frac{1}{\sin \alpha} \sqrt{v_1^2 + v_2^2 - 2v_1v_2 \cos \alpha}$$

$$6-10 \quad v_C = 0.436 (\text{m/s})$$

$$6-11 \quad v = 0.10 (\text{m/s}), a = 0.346 (\text{m/s}^2)$$

$$6-12 \quad v = 0.173 (\text{m/s}), a = 0.05 (\text{m/s}^2)$$

$$6-13 \quad v_{BC} = 115.47 (\text{mm/s}), a_{BC} = 19.25 (\text{mm/s}^2)$$

$$6-14 \quad v_a = 0.09 (\text{m/s}), v_r = 0.157 (\text{m/s}^2); a_a = 0.09 (\text{m/s}^2), a_r = 0.173 (\text{m/s}^2)$$

$$6-15 \quad \varphi = 0, v = 0, a = 40 (\text{m/s}^2)$$

$$\varphi = 30^\circ, v = 1 (\text{m/s}), a = 34.6 (\text{m/s}^2)$$

$$\varphi = 90^\circ, v = 2 (\text{m/s}), a = 0$$

$$6-16 \quad v_M = u / \sin \varphi, a_M = u^2 / r \sin^3 \varphi$$

$$6-17 \quad \omega_{BC} = 2 (\text{rad/s}), \alpha_{BC} = 16 (\text{rad/s}^2)$$

$$6-18 \quad v_B = 0.592 (\text{m/s}), a_B = 11.3 (\text{m/s}^2)$$

$$6-19 \quad \omega_1 = \frac{\omega}{2}; \alpha_1 = \frac{\sqrt{3}}{12} \omega^2, \text{逆时针转向。}$$

$$6-20 \quad a_a = 2.88 (\text{m/s}^2), \angle(a_a, i) = 236.3^\circ$$

$$6-21 \quad a = \frac{1}{R} [v_r^4 + R^4 \omega^4 \cos^2 \varphi + 2\omega^2 v_r^2 (1 + \sin^2 \varphi) R^2]^{1/2}$$

$$6-22 \quad a_a = \sqrt{\left(\frac{v_r^2}{\rho} - 2\omega v_r\right)^2 - 2r\omega^2 \left(\frac{v_r^2}{\rho} - 2\omega v_r\right) \cos \varphi + r^2 \omega^4}$$

$$\tan(a_a, i) = -\cot \varphi + \frac{r\omega^2}{\left(\frac{v_r^2}{\rho} - 2\omega v_r\right) \sin \varphi}$$

$$6-23 \quad \omega = 2 (\text{rad/s}) (\text{逆时针转向}), \alpha = 8 (\text{rad/s}^2) (\text{顺时针转向})$$

$$6-24 \quad \omega = 0.75 (\text{rad/s}) (\text{顺时针转向}), \alpha = 4.56 (\text{rad/s}^2) (\text{顺时针转向})$$

$$6-25 \quad v_E = 7.07 (\text{m/s}) (\perp AB), a_E = 141.4 \text{ m/s}^2 (\text{沿 } EA), \rho = 0.354 (\text{m})$$

$$6-26 \quad a_{Aa} = 65.5 (\text{m/s}^2), \cos(a_{Aa}, i) = -0.458, \cos(a_{Aa}, j) = 0.889;$$

$$a_{Ba} = 11.7 (\text{m/s}^2), \cos(a_{Ba}, i) = -0.077, \cos(a_{Ba}, j) = 0.997;$$

$$a_{BA} = 54.9 (\text{m/s}^2), \cos(a_{BA}, i) = 0.53, \cos(a_{BA}, j) = -0.848$$

$$6-27 \quad v_r = 94 (\text{km/h}) (\text{铅垂向上}), a_r = -1191i + 151j (\text{km/h}^2)$$

$$6-28 \quad a_a = 0.356 (\text{m/s}^2), \cos(a_a, i) = 0.974, \cos(a_a, j) = 0.112, \cos(a_a, k) = -0.195$$

$$6-29 \quad v_a = 0.12i - 0.052j + 0.03k (\text{m/s}), a_a = -0.0346i - 0.05j - 0.0173k (\text{m/s}^2)$$

$$6-30 \quad v_M = \omega \sqrt{4c^2 + b^2 + 4bcc \cos \omega t}, a_M = \omega^2 \sqrt{16c^2 + 8bcc \cos \omega t + b^2}$$

第7章

$$7-1 \quad \omega_{AB} = \omega_{O_1B} = 1.73 (\text{rad/s})$$

$$7-2 \quad v_A = v_B = 33.9(\text{cm/s})$$

$$7-3 \quad \omega = \frac{2v_0}{r} \sin^2 \frac{\theta}{2}$$

$$7-4 \quad \omega_{AB} = 6(\text{rad/s}), \omega_{BD} = 4(\text{rad/s})$$

$$7-5 \quad \omega_I = \sqrt{3}\omega_0$$

$$7-6 \quad \omega_{AB} = 6.88(\text{rad/s}), v_B = 1.54(\text{m/s})$$

$$7-7 \quad \omega_{ABD} = 1.072(\text{rad/s}), v_D = 0.254(\text{m/s})$$

$$7-8 \quad v_M = \frac{b\omega \sin(\alpha + \beta)}{a \cos \alpha}$$

$$7-9 \quad \omega_{BC} = 8(\text{rad/s}), v_C = 1.87(\text{m/s})$$

$$7-10 \quad v_F = 63(\text{mm/s})$$

$$7-11 \quad \omega_2 = 4(\text{rad/s}), v_C = 400(\text{mm/s}), \omega_{CD} = 1(\text{rad/s})$$

$$7-12 \quad \omega_O = \omega_{AB} = 0.4(\text{rad/s})$$

$$7-13 \quad v_r = \frac{2\sqrt{3}}{3} \alpha \omega_0$$

$$7-14 \quad \omega_{O_1C} = 6.19(\text{rad/s})$$

$$7-15 \quad v_r = \frac{l \sin \varphi}{\sqrt{e^2 + l^2 + 2el \cos \varphi}} e \dot{\varphi}$$

$$7-16 \quad v_r = 77.2(\text{mm/s}), \omega_H = 0.559(\text{rad/s})$$

$$7-17 \quad v_c = \frac{2\sqrt{3}}{3} r \omega_0$$

$$7-18 \quad \omega_{AB} = 2(\text{rad/s}), \alpha_{AB} = 16(\text{rad/s}^2); a_B = 5.66(\text{m/s}^2)$$

$$7-19 \quad v_B = 2(\text{m/s}), v_C = 2.828(\text{m/s}); a_B = 8(\text{m/s}^2), a_C = 11.31(\text{m/s}^2)$$

$$7-20 \quad v_C = \frac{3}{2} r \omega_0, a_C = \frac{\sqrt{3}}{12} r \omega_0^2$$

$$7-21 \quad a_C = 3150(\text{m/s}^2), a_C = 2100(\text{m/s}^2)$$

$$7-22 \quad v_B = 0, v_C = 1(\text{m/s}), a_B = 17.07(\text{m/s}^2), a_C = 10(\text{m/s}^2)$$

$$7-23 \quad a_B = \frac{\sqrt{2}}{2} r \omega_0^2, \alpha_{O_1B} = \frac{1}{2} \omega_0^2$$

$$7-24 \quad v_1 = 1.26(\text{m/s}), a_1 = 2.79(\text{m/s}^2)$$

$$7-25 \quad v_{CD} = \frac{0.2}{3} \sqrt{3}(\text{m/s}), a_{CD} = \frac{2}{3}(\text{m/s}^2)$$

$$7-26 \quad a_{DG} = 10.74(\text{m/s}^2)(\downarrow), \alpha_{BC} = 22.8(\text{rad/s}^2)$$

$$7-27 \quad \alpha_{BO} = 24.44(\text{rad/s}^2), a_O = 20.67(\text{m/s}^2), \alpha_O = 68.89(\text{rad/s}^2)$$

$$7-28 \quad v_P = 628(\text{mm/s}), a_P = 2.48(\text{m/s}^2)$$

$$7-29 \quad v_E = \frac{v}{2}, a_E = \frac{7}{8\sqrt{3}} \frac{v^2}{b}; \omega_{OC} = \frac{3}{4} \frac{v}{b}, \alpha_{OC} = \frac{3\sqrt{3}}{8} \frac{v^2}{b^2}$$

$$7-30 \quad v'_C = 6.865 r \omega_0, a'_C = 16.14 r \omega_0^2$$

- 7-31 $\alpha_3 = 0.29(\text{rad/s}^2)$, $a_r = 65(\text{mm/s}^2)$
 7-32 $v_{r1} = 0.6(\text{m/s})$, $v_{r2} = 0.9(\text{m/s})$, $v_M = 0.459(\text{m/s})$;
 $a_{r1} = 2.816(\text{m/s}^2)$, $a_{r2} = 4.592(\text{m/s}^2)$, $a_M = 2.5(\text{m/s}^2)$
 7-33 $\alpha_{AC} = 2.87(\text{rad/s}^2)$, $a_r = 545.3(\text{mm/s}^2)$
 7-34 $n_1 = 88(\text{r/min})$
 7-35 $n_H = 214(\text{r/min})$

第8章

- 8-1 当 $\varphi = 0^\circ$ 时, $F = -2.42(\text{kN})$; 当 $\varphi = 90^\circ$ 时, $F = 0$
 8-2 $v_{\max} = \sqrt{f r g}$
 8-3 $N_{\max} = 5.84(\text{kN})$, $N_{\min} = 5.36(\text{kN})$
 8-4 $T = W \cos \alpha$; $T = W(3 - 2 \cos \alpha)$
 8-5 $0.0659(\text{m})$
 8-6 $S_1 = \frac{Wl}{2ga}(a\omega^2 + g)$, $S_2 = \frac{Wl}{2ga}(a\omega^2 - g)$,
 8-7 $y = \frac{1}{2}gt^2 + v_0 t \sin \alpha$
 8-8 $\theta_{\max} = 42.7^\circ$
 8-9 (1) $v_0^2 \geq v_2^2 + 2gH$; (2) $\cos \alpha = v_1/v_0$
 8-10 $t = 18(\text{s})$
 8-11 $x = \frac{F_0}{m\omega^2}(1 - \cos \omega t) + v_0 t$
 8-12 $x = \frac{v_0}{k}(1 - e^{-kt})$
 8-13 $v_1 = \frac{v_0}{\sqrt{1 + kv_0^2/g}}$
 8-14 $v = 6.47(\text{km/s})$, $t = 19(\text{min})$
 8-15 $s = 3(\sqrt[3]{5t+1} - 1)(\text{m})$
 8-16 $a = g \tan \alpha$, $a_{\max} = \tan^{-1} \frac{a+fg}{g-fa}$
 8-17 $\cos \alpha = \frac{g}{l\omega^2} \left(\omega > \sqrt{\frac{g}{l}} \right)$
 8-18 $a_r = 11.83(\text{m/s}^2)$, $N = 4.49(\text{N})$; $x = 5.91t^2$
 8-19 $x = ch\omega t$, $F_N = 2ma\omega^2 \text{sh}\omega t$; $t_1 = 1.31/\omega$

第9章

- 9-3 $p = (2m_2 + m_1)v$

$$9-4 \quad p = \frac{5}{2}ml_1\omega, \text{ 方向水平相右}$$

$$9-5 \quad \begin{cases} x_c = Ml \cos \omega t \\ y_c = Ml \sin \omega t \end{cases} \quad \text{其中 } M = \frac{5m_1 + 4m_2}{2(3m_1 + 2m_2)};$$

$$p = \frac{1}{2}(5m_1 + 4m_2)l\omega, p \perp OC \text{ 指向与 } \omega \text{ 一致}$$

$$9-6 \quad F_R = (m_1 + m_2 + m_3 + m_4)g + \frac{1}{2}(m_1 - 2m_2 + m_3)a$$

$$9-7 \quad \Delta v = 0.42(\text{m/s})$$

$$9-8 \quad 30(\text{N})$$

$$9-9 \quad N_x = \rho Q(v_1 + v_2 \cos \alpha)$$

$$9-10 \quad (1) F_N = \sqrt{N_x^2 + N_y^2} = 277.7(\text{N}); (2) F_N = \sqrt{N_x^2 + N_y^2} = 623.7(\text{N})$$

$$9-11 \quad \text{左移 } 0.266(\text{m})$$

$$9-12 \quad \Delta x = 37.8(\text{mm}) (\text{向右})$$

$$9-13 \quad \frac{(x_A - l \cos \varphi_0)^2}{l} + \frac{y_A^2}{4l^2} = 1$$

$$9-14 \quad x = -\frac{Q}{P+Q}e \sin \omega t$$

$$9-15 \quad N_x = -\frac{P+Q}{g}e\omega^2 \cos \omega t$$

$$9-16 \quad x = \frac{Pl}{P+Q} \sin(\varphi_0 \cos kt)$$

$$9-18 \quad X_0 = \frac{P}{g}l\omega^2 + P \sin \varphi, Y_0 = P \cos \varphi - \frac{P}{g}l\varepsilon$$

$$9-20 \quad v = 60(\text{m/s})$$

$$9-21 \quad F_p = rv(gt + v), N = rg(l - vt)$$

$$9-22 \quad x = \frac{v_r}{\alpha}[(1 - \alpha t) \ln(l - \alpha t) + \alpha t] - \frac{1}{2}gt$$

第 10 章

$$10-1 \quad (a) L_0 = \frac{1}{2}(4m + M)Rv; (b) L_0 = \frac{1}{2}(4m + M)Rv$$

$$10-2 \quad L_{AB} = 2m\omega l^2 \sin \alpha$$

$$10-3 \quad (a) L_0 = 18(\text{kg} \cdot \text{m}^2/\text{s}); (b) L_0 = 20(\text{kg} \cdot \text{m}^2/\text{s}); (c) L_0 = 16(\text{kg} \cdot \text{m}^2/\text{s})$$

$$10-4 \quad (1) P = \frac{R+e}{R}mv_A, L_B = [J_A - me^2 + m(R+e)^2] \frac{v_A}{R};$$

$$(2) P = m(v_A + e\omega), L_B = (J_A + mR \cdot e)\omega + m(R+e)v_A$$

$$10-5 \quad a = 2.17(\text{m/s}^2), F_T = 598(\text{N})$$

$$10-6 \quad \alpha = \frac{m_1 r_1 - m_2 r_2}{J_0 + m_1 r_1^2 + m_2 r_2^2}$$

$$10-7 \quad n_2 = 34 \text{ (r/min)}$$

$$10-8 \quad \alpha = -0.5 \text{ (rad/s}^2\text{)}$$

$$10-10 \quad \alpha = \frac{a}{a^2 + \rho_c^2} g; R_n = 0, R_\tau = -\frac{\rho_c^2}{a^2 + \rho_c^2} mg$$

$$10-11 \quad r = \sqrt{r_0^2 + \frac{M_0}{2m\omega^2} \sin \omega t}$$

$$10-12 \quad M_f = 47.1 \text{ (N} \cdot \text{m)}$$

$$10-13 \quad \varphi = \frac{\delta_0}{l} \sin \left(\sqrt{\frac{k}{3(m_1 + 3m_2)}} t + \frac{\pi}{2} \right), T = 2\pi \sqrt{\frac{3(m_1 + 3m_2)}{k}}$$

$$10-15 \quad t = 4m/3kba^2\omega_0$$

$$10-16 \quad \alpha_1 = 2(MR_2 - M'R_1)/(m_1 + m_2)R_1^2R_2$$

$$10-17 \quad a = R(Mk - mgR)/mR^2 + k^2J_1 + J_2$$

$$10-18 \quad n = \frac{br\omega^2 P}{8\pi fglQ}$$

$$10-19 \quad J_z = \frac{1}{3}m_1l^2 + m_2\left(\frac{3}{8}d^2 + l^2 + ld\right)$$

$$10-20 \quad J_A = J_B + m(a^2 - b^2)$$

$$10-21 \quad J_O = 0.0347 \text{ (kg} \cdot \text{m}^2\text{)}$$

$$10-22 \quad J_x = \frac{1}{6}mh^2$$

$$10-23 \quad f \geq \frac{1}{3} \tan \alpha$$

$$10-24 \quad v_0 = \frac{2}{3}\sqrt{3gh}, F_T = \frac{1}{3}mg$$

$$10-25 \quad a = [F - f'(m_1 + m_2)g]/\left(m_1 + \frac{1}{3}m_2\right)$$

$$10-26 \quad a = \frac{4}{7}g \sin \alpha, F_s = \frac{1}{7}mg \sin \alpha$$

$$10-27 \quad t = (v_0 - r\omega_0)/3f'g, v_c = \frac{1}{3}(2v_0 + r\omega_0)$$

$$10-28 \quad a_c = 3.49 \text{ (m/s}^2\text{)}$$

$$10-29 \quad N_A = mg\left(1 - \frac{3}{4}\sin^2 \theta\right), N_B = \frac{3}{4}mg \sin \theta \cos \theta$$

$$10-30 \quad \alpha = \frac{3g}{2l}, x_A = \frac{3W}{4g}l\omega^2, y_A = \frac{W}{4}$$

$$10-31 \quad a_c = \frac{4}{5}g = 7.84 \text{ (m/s}^2\text{)}, F_T = 15.68 \text{ (N)}$$

第 11 章

$$11-2 \quad \frac{\omega_2}{2} \left[J_1 + J_2 \left(\frac{R}{r} \right)^2 + mR^2 \right]$$

$$11-3 \quad T = \frac{P}{6g} l^2 \omega^2 \sin^2 x$$

$$11-4 \quad T = 18352 \text{ MNcm}$$

$$11-5 \quad T = mv^2$$

$$11-7 \quad W_{AB} = mgr_0(1 + \cos \varphi), \quad W_{ABC} = mgr_0(\cos \varphi - \sin \theta)$$

$$11-8 \quad v_1 = 2.638 \text{ (m/s)}, \quad v_2 = 0$$

$$11-9 \quad 1.2 \text{ (m)}$$

$$11-10 \quad v_1 = \sqrt{\frac{4gh(P - 2Q + W_2)}{2P + 8Q + 4W_1 + 3W_2}}$$

$$11-11 \quad 0.113 \text{ (m)}$$

$$11-12 \quad \omega^2 = \frac{3ag(P_1 a + P_2 l)}{r(P_1 a^2 + P_2 l^2)}$$

$$11-13 \quad v = \sqrt{\frac{3}{m} [M\theta - mgl(1 - \cos \theta)]}$$

$$11-14 \quad (1) \text{ 圆盘的角速度 } \omega_B = 0, \text{ 连杆的角速度 } \omega_{AB} = 4.95 \text{ (rad/s)}; (2) \delta_{\max} = 87.1 \text{ (mm)}$$

$$11-15 \quad a = \frac{R(iM + Rmg)}{(J_1 + i^2 J_2 + mR^2)}$$

$$11-16 \quad \omega = \frac{2}{R+r} \sqrt{\frac{3gM}{9P+2Q}} \varphi, \quad \alpha = \frac{6gM}{(R+r)^2(9P+2Q)}$$

$$11-17 \quad v = \sqrt{\frac{2g(M - P \cdot r \sin \alpha)s}{(P+Q)r}}$$

$$11-18 \quad v_B = 3.984 \text{ (m/s)}$$

$$11-19 \quad \omega = \sqrt{\frac{3g}{2a}}, \quad x^2 = 3ay;$$

$$11-20 \quad \omega_a = \frac{2.47}{\sqrt{a}} \text{ (rad/s)}, \quad \omega_b = \frac{3.12}{\sqrt{a}} \text{ (rad/s)}$$

$$11-21 \quad a_A = \frac{3m_1 g}{4m_1 + 9m_2}$$

$$11-22 \quad v_A = \sqrt{\frac{2glP_2^2}{P_1(P_1 + P_2)}}, \quad v_B = \sqrt{\frac{2glP_1}{P_1 + P_2}}$$

$$11-23 \quad (1) \alpha_1 = \sin^{-1} \left(\frac{2}{3} \sin \alpha \right); \quad (2) \omega_{AB} = \left[\frac{3g \sin \alpha}{l} \left(1 - \frac{\sin^2 \alpha}{9} \right) \right]^{1/2}$$

$$11-24 \quad \cos \alpha = \frac{4}{7}, \quad \omega = \sqrt{\frac{4g}{7r}}$$

$$11-26 \quad \tan \alpha = \frac{1}{2}, \alpha = 26.6^\circ$$

$$11-27 \quad \theta = \arccos(\sqrt{n^2+1}-n), n = \frac{l\omega_0^2}{6g}$$

$$11-28 \quad 188(\text{N} \cdot \text{m}), 42.5(\text{N} \cdot \text{m}); 6.31(\text{kW})$$

$$11-29 \quad M = 111(\text{N} \cdot \text{m}), N = 6.75(\text{kW})$$

$$11-30 \quad (1) \theta = \arccos\left[\frac{h}{l}\left(\frac{3}{2} + \cos \beta\right) - \frac{3}{2}\right]; (2) \text{张力增加: } 2mg \frac{h}{l}\left(\frac{3}{2} + \cos \beta\right)$$

$$11-31 \quad (1) a = a_r = g/2 = 4.9(\text{m/s}^2), F_A = 72(\text{N}), F_B = 268(\text{N})$$

$$(2) a = (2 - \sqrt{3})g = 2.63(\text{m/s}^2), F_A = F_B = 248.5(\text{N})$$

$$11-32 \quad a_B = \frac{m_1 g \sin 2\theta}{2(m_2 + m_1 \sin^2 \theta)}$$

$$11-33 \quad F = \frac{M(m_1 + 2m_2)}{2R(m_1 + m_2)}$$

$$11-34 \quad a_{BC} = -r\omega^2 \cos \omega t; F_{Ox} = -r\omega^2 \left(\frac{m_1}{2} + m_2\right) \cos \omega t, F_{Oy} = m_1 g - \frac{1}{2}m_1 r\omega^2 \sin \omega t;$$

$$M = r \left(\frac{1}{2}m_1 g + m_2 r^2 \omega \sin \omega t\right) \cos \omega t$$

$$11-35 \quad (1) a_A = \frac{1}{6}g; (2) F = \frac{4}{3}mg, F_{Kx} = 0, F_{Ky} = 4.5mg; (3) M_K = 13.5mgR$$

$$11-36 \quad v_A = \frac{\sqrt{km_2}(l-l_0)}{\sqrt{m_1(m_1+m_2)}}, v_B = \frac{\sqrt{km_1}(l-l_0)}{\sqrt{m_2(m_1+m_2)}}$$

$$11-37 \quad v_r = \sqrt{\frac{8}{3}gr}, F_N = \frac{11}{3}mg$$

$$11-38 \quad \omega = \sqrt{\frac{3g}{2l}}, x_C^2 + 3ly_C + 3l^2 = 0$$

$$11-39 \quad F_N = \frac{7}{3}mg \cos \theta, F_f = \frac{1}{3}mg \sin \theta$$

$$11-40 \quad a = \frac{Q \sin \alpha - P}{2Q + P}g, F_T = \frac{3PQ + (2PQ + Q^2) \sin \alpha}{2(2Q + P)}$$

$$11-41 \quad v_B = 0.48(\text{m/s})$$

第 12 章

$$12-1 \quad g \tan(\theta - \varphi_m) \leq a \leq g \tan(\theta + \varphi_m)。$$

$$12-2 \quad a = \frac{g \sin \alpha}{\cos(\alpha + \beta)}, F_T = \frac{mg \cos \beta}{\cos(\alpha + \beta)}。$$

$$12-3 \quad F_P = 180(\text{N}); N_A = 232.5(\text{N}); N_B = 367.5(\text{N})$$

$$12-4 \quad 0.667(\text{N/mm})$$

$$12-5 \quad a = 8.49(\text{m/s}^2); S_{BF} = 175.2(\text{N}), S_{CH} = 69.8(\text{N})$$

$$12-6 \quad \omega_{\max} = \sqrt{\frac{g}{e}}, N = m(g - e\omega^2 \cos \omega t)$$

$$12-7 \quad a_{\max} = 0.35g$$

$$12-8 \quad \alpha = \frac{3g}{4a}; X_A = \frac{3}{8}mg(\rightarrow), Y_A = \frac{5}{8}mg(\uparrow)$$

$$12-9 \quad (1) N_A = \frac{mg}{4}(\uparrow); (2) \alpha_B = \frac{3g}{2l}$$

$$12-10 \quad x_A = m r \alpha - \frac{m}{2} l \omega^2(\leftarrow), y_A = -\frac{m}{2} l \alpha - m r \omega^2(\downarrow), M_A = \frac{m}{2} l r \omega^2 + \frac{m}{3} l^2 \alpha$$

$$12-11 \quad N_A = N_B = \frac{Pl^2 \omega^2}{6(a+b)g} \sin 2\alpha (\text{指向水平, 组成逆时针力偶})$$

$$12-12 \quad a_A = \frac{2(4P-kx)}{15P}g, F_{T2} = \frac{P+kx}{5}, F_S = \frac{2P+7kx}{30}$$

$$12-13 \quad \omega^2 = 3g \frac{b^2 \cos \varphi - a^2 \sin \varphi}{(b^3 - a^3) \sin 2\varphi}$$

$$12-14 \quad X_A = 3.53(\text{kN})(\rightarrow), Y_A = 19.36(\text{kN})(\uparrow); N_B = 13.83(\text{kN})(\uparrow)$$

$$12-15 \quad (1) \alpha = 3.53(\text{rad/s}^2); T = 176(\text{N}); N_A = 358(\text{N})$$

$$12-16 \quad F_{AB} = \frac{2}{9} m \omega_0^2 r + 2mg + \frac{\sqrt{3}F}{3r}, M_0 = \frac{2\sqrt{3}}{3} m \omega_0^2 r^2 + Fr$$

$$12-17 \quad (1) \alpha = 1.85(\text{rad/s}^2); (2) F_P = 64(\text{N}); (3) F_T = 321(\text{N})$$

$$12-18 \quad a_C = 2.8(\text{m/s}^2)$$

$$12-19 \quad a_C = \frac{4}{7}g \sin \alpha, S_{AB} = \frac{1}{7}mg \sin \alpha; N_C = mg \cos \alpha, F_C = \frac{4}{7}mg \sin \alpha$$

$$N_D = mg \cos \alpha, F_D = \frac{2}{7}mg \sin \alpha$$

$$12-20 \quad (1) a = \frac{m_1 \sin \alpha - m}{2m_1 + m}g; (2) T_{CD} = \frac{3m + (2m + m_1) \sin \alpha}{2(2m_1 + m)}m_1g$$

$$(3) X_O = \frac{3m + (2m + m_1) \sin \alpha}{2(2m_1 + m)}m_1g \cos \alpha$$

$$Y_O = \frac{m_1}{2(2m_1 + m)}\{4m_1 + 6m + [5m + (2m + m_1) \sin \alpha] \sin \alpha\}g$$

$$(4) F_A = \frac{m_1 \sin \alpha - m}{2(m_1 + m)}m_1g$$

$$12-21 \quad N_A = N_B = 1098(\text{N})$$

$$12-22 \quad \text{静反力 } Y_A = 27.4(\text{kN}), Y_B = 21.6(\text{kN})$$

$$\text{动反力 } X_A = -89.6(\text{kN}), Y_A = -22.7(\text{kN})$$

$$X_B = -38.4(\text{kN}), Y_B = -75.9(\text{kN})$$

$$12-24 \quad Y_A = -Y_B = \frac{PR^2 \omega^2}{8g(m+n)} \sin 2\alpha$$

第 13 章

$$13-1 \quad \frac{F_P}{F_Q} = \frac{\cos \varphi \cos \psi}{\sin(\varphi - \psi)}$$

$$13-2 \quad F_Q = \frac{F_P}{2} \tan \alpha$$

$$13-3 \quad F_P = \frac{M}{a} \cot 2\theta$$

$$13-4 \quad F = \frac{F_P l}{a} \sec^2 \varphi$$

$$13-5 \quad F_Q = 3F_P$$

$$13-6 \quad F_Q = 1.5P \cot \theta$$

$$13-7 \quad x = a + \frac{P}{k} \left(\frac{l}{b} \right)^2$$

$$13-8 \quad M = 450 \frac{\sin \theta (1 - \cos \theta)}{\cos^3 \theta}$$

$$13-9 \quad \sin \varphi = \sin \varphi_0 + \frac{5F_P}{8kl}$$

$$13-10 \quad \frac{\cos \theta}{\sin^3 \theta} = \frac{a}{r}$$

$$13-11 \quad k = 1.69 (\text{N/mm})$$

$$13-12 \quad \varphi = 0^\circ \text{ 时, 不稳定平衡位置;}$$

$$\varphi = 180^\circ \text{ 时, 当 } \frac{a}{2kl} = \lambda \geq \frac{2}{3} \text{ 为稳定平衡, 当 } \lambda < \frac{2}{3} \text{ 为不稳定平衡;}$$

$$\varphi = \arccos \frac{5 - (1 - \lambda)^{-2}}{4} \text{ 为不稳定平衡}$$

$$13-13 \quad \theta = 0^\circ \text{ 不稳定, } \theta = 53.8^\circ \text{ 稳定。}$$

$$13-14 \quad \varphi = 0^\circ \text{ 时, 不稳定; } \varphi = \arcsin \left(\frac{F_G}{2kl} + \frac{1}{\sqrt{2}} \right), \text{ 稳定}$$

$$13-15 \quad (F_{P1} + F_{P2}) \cos \varphi_1 - F_{P3} \sin \varphi_1 - 2F_{P3} \lambda \sin \varphi_1 \cos \varphi_1 - 2F_{P2} \lambda \sin \varphi_1 \cos \varphi_2 - \frac{M}{l} = 0$$

$$F_{P2} \cos \varphi_2 - F_{P3} \sin \varphi_2 - 2F_{P3} \lambda \cos \varphi_1 \sin \varphi_2 - 2F_{P3} \lambda \sin \varphi_2 \cos \varphi_2 = 0$$

$$\text{式中 } \lambda = [1 - (\sin \varphi_1 + \sin \varphi_2)^2]^{-1/2}$$

$$13-16 \quad N_A = 250 (\text{N}), M_A = 450 (\text{N} \cdot \text{m}); N_D = 1050 (\text{N}); N_G = 100 (\text{N})$$

$$13-17 \quad S_{BD} = \frac{\sqrt{3}}{\sqrt{3} - 1} F_P (\text{拉})$$

$$13-18 \quad F_A = 2.44 (\text{kN}), F_B = 2.22 (\text{kN}), F_C = 2.67 (\text{kN}), F_E = 2.67 (\text{kN})$$

$$13-19 \quad F_A = 3 (\text{kN}), M_A = 4 (\text{kN} \cdot \text{m})$$

$$13-20 \quad F_{N1} = \frac{11}{3} \text{ kN (拉)}, F_{N2} = -\frac{11}{2} \text{ kN (压)}$$

$$13-21 \quad F_{Ax} = 1 (\text{kN}), F_{Ay} = 1 (\text{kN}); F_B = 2 (\text{kN})$$

$$13-22 \quad F_{N1} = F (\text{拉}), F_{N2} = \sqrt{2} F (\text{拉})$$

$$13-23 \quad k \leq \frac{G(r+a)}{4a^2}$$

$$13-24 \quad m = 6.5 (\text{kg}), \text{稳定平衡}$$

$$13-25 \quad \theta = 0^\circ; \theta = 180^\circ, \text{不稳定平衡}; \theta = 68.7^\circ, \text{稳定平衡}$$

$$13-26 \quad \theta = \arctan \frac{1}{3}, \text{稳定平衡}$$

第 14 章

$$14-1 \quad a_1 = \frac{1}{11}g, a_2 = \frac{3}{11}g, a_3 = -\frac{1}{11}g$$

$$14-2 \quad a_A = \frac{P(R-r)^2}{P(R-r)^2 + Q(\rho^2 + r^2)}g$$

$$14-3 \quad \alpha = \frac{M_0}{a^2(3m + 4m_1)}$$

$$14-4 \quad \ddot{\varphi} + \frac{g}{l} \sin \varphi = 0, l^2 [l^2 - x^2] \ddot{x} + x \dot{x}^2 + gx(l^2 - x^2)^{3/2} = 0$$

$$l^2 [(l^2 - y^2) \ddot{y} + y \dot{y}^2] - g = 0$$

$$14-5 \quad \ddot{\varphi} + \frac{2g}{3(R-r)}\varphi = 0$$

$$14-6 \quad (l + r\theta) \ddot{\theta} + r\dot{\theta}^2 + g \sin \theta = 0$$

$$14-7 \quad 27\ddot{\varphi} + 400\varphi = 0 \quad (\text{平衡位置为中心})$$

$$14-8 \quad \ddot{x} + \left(\frac{k_1 b^2 + k_2 a^2}{b^2 m + J} \right) x = 0$$

$$14-9 \quad m_1 \ddot{x}_1 + (k_1 + k_2)x_1 - k_2 x_2 = 0, m_2 \ddot{x}_2 + k_2 x_2 - k_2 x_1 = 0$$

$$14-10 \quad (m_1 + m_2) \ddot{x} + m_2 l \ddot{\varphi} + kx = 0, \ddot{x} + l \ddot{\varphi} + g\varphi = 0$$

$$14-11 \quad m \ddot{z} = -k_1(z - l_1\varphi) - k_2(z + l_2\varphi), m\rho^2 \ddot{\varphi} = k_1 l_1(z - l_1\varphi) - k_2 l_2(z + l_2\varphi)$$

$$14-12 \quad \frac{d}{dt} [J\beta \dot{\theta}_0 + m(L+x)^2 \dot{\theta}] = 0, m\ddot{x} - m(L+x)\dot{\theta}^2 + kx = 0$$

$$14-13 \quad \rho^2 > \frac{\frac{M}{2} + m}{m - m'} r^2$$

$$14-14 \quad 5\ddot{\varphi} + 3\ddot{\theta} = 0, \ddot{\varphi} + 2\ddot{\theta} + \frac{g}{r}\theta = 0$$

$$14-15 \quad \left(m + \frac{M}{2} \right) R^2 \ddot{\varphi} + mRl \cos(\varphi + \psi) \ddot{\psi} + mrl \sin(\varphi - \psi) \dot{\psi}^2 + mgR \sin \varphi = 0$$

$$mRl\cos(\varphi-\psi)\ddot{\varphi}+ml^2\ddot{\psi}-mRl\sin(\varphi-\psi)\dot{\varphi}^2+mgl\sin\psi=0$$

$$14-16 \quad \ddot{x} = \frac{6M+6m+2M_1}{6M+2M_1+9m}g\sin\alpha$$

$$14-17 \quad \text{能积分为 } \frac{3}{4}M\dot{x}^2 + \frac{1}{2}kx^2 - Mgx\sin\alpha = E; \text{ 周期为 } T = 2\pi\sqrt{\frac{3M}{2k}}$$

第 15 章

$$15-1 \quad v_A = v_B = \frac{G_1\sqrt{2gh}}{G_1+G_2}$$

$$15-2 \quad e = 0.358$$

$$15-3 \quad F_R = 529.2(\text{kN})$$

$$15-4 \quad \delta_{\max} = 11.29(\text{cm}); F_{\max} = 442.7(\text{kN})$$

$$15-5 \quad AB = \frac{2eI}{m}\sqrt{\frac{2h}{g}}$$

$$15-6 \quad \eta = 0.8; \Delta T = 39.2(\text{kN} \cdot \text{m})$$

$$15-7 \quad G_1 = 10671(\text{N}), G_2 = 42684(\text{N}); T_1 = 19600(\text{N} \cdot \text{m}), T_2 = 4900(\text{N} \cdot \text{m})$$

$$15-8 \quad G = 28.8(\text{t})$$

$$15-9 \quad v'_1 = 2.625(\text{m/s})$$

$$15-10 \quad v'_1 = 9.72(\text{m/s}), (v'_1)_n = 31^\circ 58'; v'_2 = 4.04(\text{m/s}), \text{水平向右}$$

$$15-11 \quad \omega_2 = \frac{J_0}{J_0+mR^2}\omega_1, v = \frac{J_0}{J_0+mR^2}R\omega_1, I = m \frac{J_0}{J_0+mR^2}R\omega_1$$

$$15-12 \quad x = \left(\frac{M}{M+3m}\right)^2 \frac{3l}{2f'}$$

$$15-13 \quad \omega = \frac{6v}{7l}$$

$$15-15 \quad \omega = \frac{3v}{4a}; I_x = \frac{5}{8}Mv, I_y = \frac{3}{8}Mv; \Delta T = \frac{5}{16}Mv^2$$

$$15-16 \quad \tan\beta = \frac{1}{5e}\left(3\tan\alpha - \frac{2r\omega_0}{v\cos\alpha}\right)$$

$$15-17 \quad \omega = 5.78(\text{rad/s}), v_c = 1.73(\text{m/s}); I_\tau = 1.33(\text{N} \cdot \text{s}), I_\eta = 12(\text{N} \cdot \text{s})$$

$$15-18 \quad d = \frac{\sqrt{3}l}{3}$$

$$15-19 \quad (b/a)_{\max} = \frac{\sqrt{2}}{2} = 0.707$$

$$15-20 \quad e = \sqrt{2}\sin\frac{\varphi}{2}; x = \frac{2}{3}l$$

$$15-21 \quad I = \frac{3}{5}m\sqrt{gl}$$

$$15-22 \quad l=0.37(\text{m})$$

$$15-23 \quad h=\frac{7}{10}l$$

第 16 章

$$16-1 \quad (\text{a}) T=2\pi\sqrt{\frac{m}{k}}; (\text{b}) T=2\pi\sqrt{\frac{2m}{k}}; (\text{d}) T=2\pi\sqrt{\frac{m}{2k}}; (\text{e}) T=2\pi\sqrt{\frac{2m}{k}};$$

$$(\text{f}) T=2\pi\sqrt{\frac{m}{k}}$$

$$16-2 \quad k=\frac{4\pi^2(m_1-m_2)}{T_1^2-T_2^2}$$

$$16-3 \quad y=-5\cos 44.3t+100\sin 44.3t(\text{mm})$$

$$16-4 \quad T=2\pi\sqrt{\frac{m}{k}}, A=\sqrt{\frac{mg}{k}\left(\frac{mg\sin^2\theta}{k}+2h\right)}$$

$$16-5 \quad T=\frac{2\pi r}{e}\sqrt{\frac{2m+M}{2k}}$$

$$16-6 \quad T=\frac{\pi d}{d+2a}\sqrt{\frac{3m}{k}}$$

$$16-7 \quad \omega=\frac{x}{l}\sqrt{\frac{kg}{P}}$$

$$16-8 \quad f=\frac{b}{2\pi}\sqrt{\frac{k_1k_2}{(k_1a^2+k_2b^2)m}}$$

$$16-9 \quad (1)f_n=0.182(\text{Hz}); (2)\zeta=0.289; (3)f_d=0.176(\text{Hz}); (4)T_d=5.677(\text{s})$$

$$16-10 \quad (1)0.0355; (2)8.97(\text{Ns/m})$$

$$16-11 \quad (1)\ddot{\varphi}+\frac{4c}{m}\dot{\varphi}+\frac{9k}{m}\varphi=0; (2)\omega\sqrt{\frac{9k}{m}}$$

$$16-12 \quad (1)\beta=0.385; (2)\beta=0.0013$$

$$16-13 \quad (1)y=\frac{kdl^2}{kl^2-m\pi^2v^2}\sin\frac{\pi}{l}vl; (2)v_{\text{cr}}=\frac{1}{\pi}\sqrt{\frac{k}{m}}$$

$$16-14 \quad n=945(\text{r/min}); B=0.412(\text{mm})$$

$$16-15 \quad x=40\sin 7t(\text{mm}); n_p=95.5(\text{r/min})$$

$$16-16 \quad \omega_n=\sqrt{\frac{ka^2-mgl}{ml^2}}, \varphi=\frac{kbd}{ml^2(\omega_n^2-\omega^2)}\sin\omega t$$

$$16-17 \quad k=323(\text{kN/m})$$

附录 A

$$A-6 \quad k=2, a\cos\theta+\rho\cos\varphi-b\cos\psi=1, a\sin\theta+\rho\sin\varphi-b\sin\psi=0$$

$$A-7 \quad (1)k=1; (2)r\sin\varphi-(l-\rho)\cos\psi-r\sin\theta=0;$$

$$r \cos \varphi - (l - \rho) \sin \psi - r \cos \theta = 0;$$

$$r \cos \theta + l \sin \psi = b$$

$$\text{A-8 } k=1, \sin \varphi + \cos \theta = 1$$

$$\text{A-9 } k=1, x_A^2 + y_A^2 + z_A^2 = l^2, l \cos \psi - y_A = 0, b \sin(\psi/2) - h \sin(\theta/2) = 0,$$

$$(bx_A/l)^2 + (by_A/l-b)^2 + (bz_A/l-h)^2 = h^2$$

$$\text{A-10 } k=1; l \cos \varphi + b \sin \theta - b \sin \psi = 1, l \sin \varphi + b \cos \theta + b \cos \psi = h$$

$$\text{A-11 } (1) \dot{x}_P = -cv_B/b, \dot{y} = (b+c) \cos \theta v_B/b; (2) \ddot{x}_P = 0, \ddot{y}_P = -(b+c)v_B^2/(b^2 \sin^3 \theta)$$

$$\text{A-12 } \dot{\varphi} = a \cos(\theta + \varphi) \omega / [b \cos \varphi - a \cos(\theta + \varphi)];$$

$$\ddot{\varphi} = [a \sin(\theta + \varphi)(\omega + \dot{\varphi})^2 - b \dot{\varphi}^2 \sin \varphi] / [a \cos(\theta + \varphi) - b \cos \varphi];$$

$$\dot{\rho} = (a \omega \cos \theta - \rho \dot{\varphi} \cos \varphi) / \sin \varphi;$$

$$\ddot{\rho} = (-\rho \ddot{\varphi} \cos \varphi + \rho \dot{\varphi}^2 \sin \varphi - 2\dot{\rho} \dot{\varphi} \cos \varphi - a \omega^2 \sin \theta) / \sin \varphi$$

$$\text{A-13 } \dot{\theta} = v / [4l \cos(\theta/2)], \ddot{\theta} = \theta/2 \tan(\theta/2)$$

$$\text{A-14 } \dot{x} = L \dot{\theta} \cos \varphi, \dot{x}_B = L(\dot{\varphi} \cos \varphi - \dot{\varphi}^2 \sin \varphi), \text{ 其中 } \dot{\varphi} = \frac{r \omega \cos(\theta + \omega)}{l \cos \varphi - r \cos(\theta + \varphi)},$$

$$\ddot{\varphi} = [l \dot{\varphi}^2 \sin \varphi - r \sin(\theta + \varphi)(\omega + \dot{\varphi})^2] / [l \cos \varphi - r \cos(\theta + \varphi)],$$

$$l \sin \varphi = r \sin(\theta + \varphi)$$

$$\text{A-15 } \dot{y} = -9.07(\text{cm/s}), \ddot{y} = -9.01(\text{cm/s}^2); \dot{\rho} = -15.71(\text{cm/s}); \ddot{\rho} = 17.29(\text{cm/s}^2)$$

$$\text{A-16 } \dot{\varphi} = \frac{1}{4} \omega_1, \ddot{\varphi} = -7\sqrt{3} \omega_1^2/24$$

$$\text{A-17 } \omega_{AC} = \frac{1}{3} \omega, \alpha_{AC} = 8\sqrt{3} \omega^2/27$$

$$\text{A-18 } \omega_{BD} = -1.19(\text{rad/s}), \alpha_{BO} = 16.83(\text{rad/s}^2)$$

$$\text{A-19 } v = r \omega, \alpha = 5\sqrt{3} r \omega^2/12$$

$$\text{A-20 } \sin \theta - 2 \sin \varphi + \sin \psi - 1 = 0, \cos \theta - 2 \cos \varphi + \cos \psi + 1 = 0;$$

$$\dot{\varphi} = \omega [\sin \theta + \cos \theta + \sin(\varphi - \theta)] / [\cos \varphi + \sin \varphi + \sin(\varphi - \theta)],$$

$$\ddot{\varphi} = \{ [\sin \theta + \cos \theta + \sin(\varphi - \theta)] \dot{\varphi}^2 + [\cos \theta - \sin \theta - \cos(\varphi - \theta)] \omega^2 +$$

$$2 \cos(\varphi - \theta) \dot{\varphi} \omega \} / [\cos \theta + \sin \varphi + \sin(\varphi - \theta)]$$