

习题答案

第二章

- 2-1 $F_R = 161.2 \text{ N}$, $\angle(\mathbf{F}_R, \mathbf{F}_1) = 29^\circ 44'$
- 2-2 $F_R = 5\,000 \text{ N}$, $\angle(\mathbf{F}_R, \mathbf{F}_1) = 38^\circ 28'$
- 2-3 $F_{AB} = 54.64 \text{ kN}$ (拉), $F_{CB} = 74.64 \text{ kN}$ (压)
- 2-4 $F_2 = 173 \text{ kN}$, $\gamma = 95^\circ$
- 2-5 $F_A = \frac{\sqrt{5}}{2} F \swarrow$, $F_D = \frac{1}{2} F \uparrow$
- 2-6 $F_C = 2\,000 \text{ N}$, $F_A = F_B = 2\,010 \text{ N}$
- 2-7 $F_H = \frac{F}{2\sin^2 \theta}$
- 2-8 $F = 80 \text{ kN}$
- 2-9 $F_1 : F_2 = 0.644$
- 2-10 $M_A(\mathbf{F}) = -Fb\cos \theta$, $M_B(\mathbf{F}) = F(a\sin \theta - b\cos \theta)$
- 2-11 $M_{\text{总}} = 4.5 \text{ kN}\cdot\text{m}$
- 2-12 (a)、(b) $F_A = F_B = M/l$; (c) $F_A = F_B = M/l \cdot \cos \theta$
- 2-13 $F_A = F_C = \frac{M}{2\sqrt{2}a}$
- 2-14 $M_2 = \frac{r_2}{r_1} M_1$, $F_{O1} = \frac{M_1}{r_1 \cos \theta} \swarrow$, $F_{O2} = \frac{M_1}{r_1 \cos \theta} \nearrow$
- 2-15 $F_A = \frac{20}{\sqrt{3}} \text{ kN} \swarrow$, $F_B = \frac{20}{\sqrt{3}} \text{ kN} \nearrow$, $F_{EC} = 10\sqrt{2} \text{ kN}$ (压)
- 2-16 $F_A = \sqrt{2} \frac{M}{l} \searrow$
- 2-17 $F = \frac{M}{a} \cot 2\theta$

第三章

- 3-1 $F'_R = 466.5 \text{ N}$, $M_O = 21.44 \text{ N}\cdot\text{m}$;
 $F_R = 466.5 \text{ N}$, $d = 45.96 \text{ mm}$
- 3-2 (1) $F'_R = 150 \text{ N} \leftarrow$, $M_O = 900 \text{ N}\cdot\text{mm} \downarrow$;
 (2) $F = 150 \text{ N} \leftarrow$, $y = -6 \text{ mm}$
- 3-3 $F_x = 4 \text{ kN}$, $F_{y1} = 28.73 \text{ kN}$, $F_{y2} = 1.269 \text{ kN}$

$$3-4 \quad F_{Ax} = 0, \quad F_{Ay} = 6 \text{ kN}, \quad M_A = 12 \text{ kN}\cdot\text{m}$$

$$3-5 \quad F_O = -385 \text{ kN}, \quad M_O = -1\,626 \text{ kN}\cdot\text{m}$$

$$3-6 \quad (a) \quad F_{Ax} = 0, \quad F_{Ay} = -\frac{1}{2}\left(F + \frac{M}{a}\right); \quad F_B = \frac{1}{2}\left(3F + \frac{M}{a}\right);$$

$$(b) \quad F_{Ax} = 0, \quad F_{Ay} = -\frac{1}{2}\left(F + \frac{M}{a} - \frac{5}{2}qa\right); \quad F_B = \frac{1}{2}\left(3F + \frac{M}{a} - \frac{1}{2}qa\right)$$

$$3-7 \quad (a) \quad F_A = 33.23 \text{ kN}, \quad F_B = 96.77 \text{ kN}; \quad (b) \quad P_{\max} = 52.22 \text{ kN}$$

$$3-8 \quad P_2 = 333.3 \text{ kN}; \quad x = 6.75 \text{ m}$$

$$3-9 \quad F_{Ax} = -4.661 \text{ kN}, \quad F_{Ay} = -47.62 \text{ kN}; \quad F_B = 22.4 \text{ kN}(\text{杆 } BC \text{ 受拉力})$$

$$3-10 \quad F_{BC} = 848.5 \text{ N}; \quad F_{Ax} = 2\,400 \text{ N}, \quad F_{Ay} = 1\,200 \text{ N}$$

$$3-11 \quad F_A = -48.33 \text{ kN}, \quad F_B = 100 \text{ kN}, \quad F_D = 8.333 \text{ kN}$$

$$3-12 \quad (a) \quad F_{Ax} = \frac{M}{a} \tan \theta, \quad F_{Ay} = -\frac{M}{a}, \quad M_A = -M; \quad F_B = F_C = \frac{M}{a \cos \theta}$$

$$(b) \quad F_{Ax} = \frac{qa}{2} \tan \theta, \quad F_{Ay} = \frac{1}{2}qa, \quad M_A = \frac{1}{2}qa^2; \quad F_{Bx} = \frac{qa}{2} \tan \theta, \quad F_{By} = \frac{1}{2}qa,$$

$$F_C = \frac{qa}{2 \cos \theta}$$

$$3-13 \quad F_A = -15 \text{ kN}, \quad F_B = 40 \text{ kN}, \quad F_C = 5 \text{ kN}, \quad F_D = 15 \text{ kN}$$

$$3-14 \quad M = \frac{Fr \cos(\beta - \theta)}{\sin \beta}$$

$$3-15 \quad M = 70.36 \text{ N}\cdot\text{m}$$

$$3-16 \quad M = \frac{Pr r_1}{r_2}$$

$$3-17 \quad M = \frac{r_1 r_3 r}{r_2 r_4} P; \quad F_{3x} = \frac{r}{r_4} P \tan \theta, \quad F_{3y} = P \left(1 - \frac{r}{r_4}\right)$$

$$3-18 \quad F_{Ax} = -F_{Bx} = 120 \text{ kN}, \quad F_{Ay} = F_{By} = 300 \text{ kN}$$

$$3-19 \quad F_{Ax} = 0, \quad F_{Ay} = -\frac{M}{2a}; \quad F_{Dx} = 0, \quad F_{Dy} = \frac{M}{a}; \quad F_{Bx} = 0, \quad F_{By} = -\frac{M}{2a}$$

$$3-20 \quad F_{Ax} = -F, \quad F_{Ay} = -F; \quad F_{Dx} = 2F, \quad F_{Dy} = F; \quad F_{Bx} = -F, \quad F_{By} = 0$$

$$3-21 \quad F_{Ax} = 1\,200 \text{ N}, \quad F_{Ay} = 150 \text{ N}; \quad F_B = 1\,050 \text{ N}; \quad F_{BC} = 1\,500 \text{ N}(\text{压})$$

$$3-22 \quad AC = x = a + \frac{F}{k} \left(\frac{l}{b}\right)^2$$

$$3-23 \quad F_{Ax} = -120 \text{ kN}, \quad F_{Ay} = -160 \text{ kN}; \quad F_B = 160\sqrt{2} \text{ kN}; \quad F_C = -80 \text{ kN}$$

$$3-24 \quad F_{Ax} = 267 \text{ N}, \quad F_{Ay} = -87.5 \text{ N}; \quad F_B = 550 \text{ N}; \quad F_{Cx} = 209 \text{ N},$$

$$F_{Cy} = -187.5 \text{ N}$$

$$3-25 \quad F_D = 84 \text{ kN}$$

$$3-26 \quad F_D = \frac{\sqrt{5}}{2} qa$$

$$3-27 \quad F_{Ax} = 0, \quad F_{Ay} = 15.1 \text{ kN}, \quad M_A = 68.4 \text{ kN}\cdot\text{m};$$

$$F_{Bx} = -22.8 \text{ kN}, \quad F_{By} = -17.85 \text{ kN};$$

$$F_{Cx} = 22.8 \text{ kN}, \quad F_{Cy} = 4.55 \text{ kN}$$

$$* 3-28 \quad (1) \quad F_{Ax} = \frac{3}{2}F_1, \quad F_{Ay} = F_2 + \frac{F_1}{2}, \quad M_A = -\left(F_2 + \frac{F_1}{2}\right)a;$$

$$(2) \quad F_{BAx} = -\frac{3}{2}F_1, \quad F_{BAy} = -\left(F_2 + \frac{F_1}{2}\right); \quad F_{BTx} = \frac{3}{2}F_1, \quad F_{BTy} = \frac{F_1}{2}$$

$$* 3-29 \quad F_{Ax} = -qa, \quad F_{Ay} = F + qa, \quad M_A = (F + qa)a; \quad F_{BCx} = \frac{1}{2}qa,$$

$$F_{BCy} = qa; \quad F_{BAx} = -\frac{1}{2}qa, \quad F_{BAy} = -(F + qa)$$

$$3-30 \quad F_E = \sqrt{2}F; \quad F_{Ax} = F - 6aq, \quad F_{Ay} = 2F, \quad M_A = 5aF + 18a^2q$$

$$3-31 \quad F_{Ax} = -60 \text{ kN}, \quad F_{Ay} = 30 \text{ kN}; \quad F_{BD} = 100 \text{ kN}, \quad F_{BC} = -50 \text{ kN}, \\ F_{Ex} = 60 \text{ kN}, \quad F_{Ey} = 30 \text{ kN}$$

$$3-32 \quad F_{AD} = -87.5 \text{ kN(压)}, \quad F_{AC} = 179.2 \text{ kN(拉)}$$

$$3-33 \quad F_{EF} = 8.167 \text{ kN(拉)}, \quad F_{AD} = 158 \text{ kN(压)}$$

$$3-34 \quad F_1 = -5.333F(\text{压}), \quad F_2 = 2F(\text{拉}), \quad F_3 = -1.667F(\text{压})$$

$$3-35 \quad F_{CD} = -0.866F(\text{压})$$

$$3-36 \quad F_{BD} = -240 \text{ kN(压)}, \quad F_{BE} = 86.53 \text{ kN(拉)}$$

$$3-37 \quad F_4 = 21.83 \text{ kN(拉)}, \quad F_5 = 16.73 \text{ kN(拉)}, \quad F_7 = -20 \text{ kN(压)}, \\ F_{10} = -43.64 \text{ kN(压)}$$

$$3-38 \quad F_1 = -\frac{4}{9}F(\text{压}), \quad F_2 = -\frac{2}{3}F(\text{压}), \quad F_3 = 0$$

第四章

$$4-1 \quad F_{Rx} = -345.4 \text{ N}, \quad F_{Ry} = 249.6 \text{ N}, \quad F_{Rz} = 10.56 \text{ N},$$

$$M_x = -51.78 \text{ N}\cdot\text{m}, \quad M_y = -36.65 \text{ N}\cdot\text{m}, \quad M_z = 103.6 \text{ N}\cdot\text{m}$$

$$4-2 \quad F_R = 20 \text{ N}, \text{沿 } z \text{ 轴正向, 作用线的位置由 } x_C = 60 \text{ mm 和 } y_C = 32.5 \text{ mm 来确定.}$$

$$4-3 \quad F_{Rx} = -143.9 \text{ N}, \quad F_{Ry} = 1011 \text{ N}, \quad F_{Rz} = -516.9 \text{ N};$$

$$M_x = -48 \text{ N}\cdot\text{m}, \quad M_y = 21.07 \text{ N}\cdot\text{m}, \quad M_z = -19.4 \text{ N}\cdot\text{m}$$

$$4-4 \quad M_x = -101.4 \text{ N}\cdot\text{m}$$

$$4-5 \quad M = F \sin \beta \sin \theta$$

$$4-6 \quad M_x = \frac{F}{4}(h - 3r), \quad M_y = \frac{\sqrt{3}}{4}F(r + h), \quad M_z = -\frac{Fr}{2}$$

$$4-7 \quad F_A = F_B = -26.39 \text{ kN(压)}, \quad F_C = 33.46 \text{ kN(拉)}$$

$$4-8 \quad F_{CA} = -\sqrt{2}P(\text{压}), \quad F_{BD} = P(\cos \theta - \sin \theta), \quad F_{BE} = P(\cos \theta + \sin \theta),$$

$$F_{AB} = -\sqrt{2}P \cos \theta$$

$$4-9 \quad F_1 = -5 \text{ kN(压)}, \quad F_2 = -5 \text{ kN(压)}, \quad F_3 = -7.07 \text{ kN(压)},$$

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

$$4-10 \quad a = 350 \text{ mm}$$

$$4-11 \quad F = 50 \text{ N}, \quad \theta = 143^\circ 8'$$

$$4-12 \quad (1) M = 22.5 \text{ N}\cdot\text{m}; \quad (2) F_{Ax} = 75 \text{ N}, \quad F_{Ay} = 0, \quad F_{Az} = 50 \text{ N};$$

$$(3) F_x = 75 \text{ N}, \quad F_y = 0$$

$$4-13 \quad F_{Ox} = 150 \text{ N}, \quad F_{Oy} = 75 \text{ N}, \quad F_{Oz} = 500 \text{ N};$$

$$M_x = 100 \text{ N}\cdot\text{m}, \quad M_y = -37.5 \text{ N}\cdot\text{m}, \quad M_z = -24.38 \text{ N}\cdot\text{m}$$

$$4-14 \quad F_1 = 10 \text{ kN}, \quad F_2 = 5 \text{ kN}, \quad F_{Ax} = -5.2 \text{ kN}, \quad F_{Az} = 6 \text{ kN}; \quad F_{Bx} = -7.8 \text{ kN},$$

$$F_{Bz} = 1.5 \text{ kN}$$

$$4-15 \quad F_{Ax} = -2.078 \text{ kN}, \quad F_{Az} = -5.708 \text{ kN}; \quad F_{Bx} = -1.093 \text{ kN}, \quad F_{Bz} =$$

$$-3.004 \text{ kN}; \quad F_{Cx} = -0.378 \text{ kN}, \quad F_{Cz} = 12.46 \text{ kN}; \quad F_{Dx} = -6.273 \text{ kN},$$

$$F_{Dz} = 23.25 \text{ kN}$$

$$4-16 \quad F_{Cx} = -666.7 \text{ N}, \quad F_{Cy} = -14.7 \text{ N}, \quad F_{Cz} = 12\,640 \text{ N};$$

$$F_{Ax} = 2\,667 \text{ N}, \quad F_{Ay} = -325.3 \text{ N}$$

$$4-17 \quad F = 200 \text{ N}; \quad F_{Bx} = F_{Bz} = 0; \quad F_{Ax} = 86.6 \text{ N}, \quad F_{Ay} = 150 \text{ N}, \quad F_{Az} = 100 \text{ N}$$

$$4-18 \quad F_1 = F_5 = -F(\text{压}), \quad F_3 = F(\text{拉}), \quad F_2 = F_4 = F_6 = 0$$

$$4-19 \quad M_1 = \frac{b}{a}M_2 + \frac{c}{a}M_3; \quad F_{Ay} = \frac{M_3}{a}, \quad F_{Az} = \frac{M_2}{a};$$

$$F_{Dx} = 0, \quad F_{Dy} = -\frac{M_3}{a}; \quad F_{Dz} = -\frac{M_2}{a}$$

$$4-20 \quad F_B = \frac{P_1 + P_2}{2}; \quad F_{Ax} = 0, \quad F_{Ay} = -\frac{P_1 + P_2}{2}, \quad F_{Az} = P_1 + \frac{P_2}{2};$$

$$F_{Cx} = F_{Cy} = 0, \quad F_{Cz} = \frac{P_2}{2}$$

$$4-21 \quad F_1 = F_D, \quad F_2 = -\sqrt{2}F_D, \quad F_3 = -\sqrt{2}F_D, \quad F_4 = \sqrt{6}F_D$$

$$F_5 = -F - \sqrt{2}F_D, \quad F_6 = F_D$$

$$4-22 \quad \text{重心离底面的高度为 } 0.659 \text{ m, 离 } B \text{ 端距离为 } 1.68 \text{ m}$$

$$4-23 \quad x_C = 90 \text{ mm}$$

$$4-24 \quad x_C = 21.72 \text{ mm}, \quad y_C = 40.69 \text{ mm}, \quad z_C = -23.62 \text{ mm}$$

$$4-25 \quad x_C = 21.43 \text{ mm}, \quad y_C = 21.43 \text{ mm}, \quad z_C = -7.143 \text{ mm}$$

$$4-26 \quad h = \frac{r}{\sqrt{2}}$$

第五章

$$5-1 \quad f_s = 0.223$$

$$5-2 \quad s = 0.456l$$

$$5-3 \quad f_s = \frac{1}{2\sqrt{3}}$$

$$5-4 \quad l_{\min} = 100 \text{ mm}$$

$$5-5 \quad b_{\min} = \frac{f_s h}{3}, \text{与门重无关}$$

$$5-6 \quad \frac{M \sin(\theta - \varphi)}{l \cos \theta \cos(\beta - \varphi)} \leq F \leq \frac{M \sin(\theta + \varphi)}{l \cos \theta \cos(\beta + \varphi)}$$

$$5-7 \quad b < 7.5 \text{ mm}$$

$$5-8 \quad M_{\text{制动}} = 300 \text{ N}\cdot\text{m}$$

$$5-9 \quad b \leq 110 \text{ mm}$$

$$5-10 \quad f_s \geq 0.15$$

$$5-11 \quad 49.61 \text{ N}\cdot\text{m} \leq M_C \leq 70.39 \text{ N}\cdot\text{m}$$

$$5-12 \quad 40.21 \text{ kN} \leq P_E \leq 104.2 \text{ kN}$$

$$5-13 \quad e = \frac{f_s D}{2}$$

$$* 5-14 \quad M_{\min} = 0.212 Pr$$

$$* 5-15 \quad F_{\min} = 240 \text{ N}$$

$$5-16 \quad \theta \leq 11^\circ 25' (\theta = 2\varphi_f)$$

$$5-17 \quad \varphi_A = 16^\circ 6', \quad \varphi_B = \varphi_C = 30^\circ$$

$$5-18 \quad \frac{\sin \theta - f_s \cos \theta}{\cos \theta + f_s \sin \theta} P \leq F \leq \frac{\sin \theta + f_s \cos \theta}{\cos \theta - f_s \sin \theta} P$$

$$5-19 \quad M = P_2(R \sin \theta - r); \quad F_s = P_2 \sin \theta; \quad F_N = P_1 - P_2 \cos \theta$$

$$* 5-20 \quad M = 1.867 \text{ kN}\cdot\text{m}, \quad f_s \geq 0.752$$

$$5-21 \quad \theta = 1^\circ 9'$$

$$5-22 \quad (\text{a}) F = 14.83 \text{ N}; \quad (\text{b}) F = 10.25 \text{ N}, \theta = 24.63^\circ$$

$$5-23 \quad \tan \theta = \frac{f_s a}{\sqrt{l^2 - a^2}}$$

$$5-24 \quad M = 122.5 \text{ N}\cdot\text{m}$$

第六章

$$6-1 \quad x = 200 \cos \frac{\pi}{5} t \text{ mm}, \quad y = 100 \sin \frac{\pi}{5} t \text{ mm};$$

$$\text{轨迹} \quad \frac{x^2}{40\,000} + \frac{y^2}{10\,000} = 1$$

$$6-2 \quad \frac{(x-a)^2}{(b+l)^2} + \frac{y^2}{l^2} = 1$$

$$6-3 \quad \text{对地: } y_A = 0.01 \sqrt{64 - t^2} \text{ m}, \quad v_A = \frac{0.01t}{\sqrt{64 - t^2}} \text{ m/s, 方向铅垂向下};$$

$$\text{对凸轮: } x'_A = 0.01t \text{ m}, \quad y'_A = 0.01 \sqrt{64 - t^2} \text{ m}, \quad v_{Ax'} = 0.01 \text{ m/s},$$

$$v_{Ay'} = -\frac{0.01t}{\sqrt{64 - t^2}} \text{ m/s}$$

$$6-4 \quad y = l \tan kt;$$

$$v = lk \sec^2 kt; \quad a = 2lk^2 \tan kt \sec^2 kt$$

$$\theta = \frac{\pi}{6} \text{ 时, } v = \frac{4}{3} lk, \quad a = \frac{8\sqrt{3}}{9} lk^2$$

$$\theta = \frac{\pi}{3} \text{ 时, } v = 4lk, \quad a = 8\sqrt{3} lk^2$$

$$6-5 \quad v = -\frac{v_0}{x} \sqrt{x^2 + l^2}; \quad a = -\frac{v_0^2 l^2}{x^3}$$

$$6-6 \quad y = e \sin \omega t + \sqrt{R^2 - e^2 \cos^2 \omega t}; \quad v = e\omega \left[\cos \omega t + \frac{e \sin 2\omega t}{2\sqrt{R^2 - e^2 \cos^2 \omega t}} \right]$$

$$6-7 \quad (1) \text{ 自然法: } s = 2R\omega t; \quad v = 2R\omega; \quad a_t = 0, \quad a_n = 4R\omega^2;$$

$$(2) \text{ 直角坐标法: } x = R + R \cos 2\omega t, \quad y = R \sin 2\omega t$$

$$v_x = -2R\omega \sin 2\omega t, \quad v_y = 2R\omega \cos 2\omega t;$$

$$a_x = -4R\omega^2 \cos 2\omega t, \quad a_y = -4R\omega^2 \sin 2\omega t$$

$$6-8 \quad v = ak, \quad v_t = -ak \sin kt$$

$$6-9 \quad x = r \cos \omega t + l \sin \frac{\omega t}{2}, \quad y = r \sin \omega t - l \cos \frac{\omega t}{2}$$

$$v = \omega \sqrt{r^2 + \frac{l^2}{4} - rl \sin \frac{\omega t}{2}}; \quad a = \omega^2 \sqrt{r^2 + \frac{l^2}{16} - \frac{rl}{2} \sin \frac{\omega t}{2}}$$

$$6-10 \quad \rho = 5 \text{ m}, \quad a_t = 8.66 \text{ m/s}^2$$

$$6-11 \quad v_M = v \sqrt{1 + \frac{p}{2x}}; \quad a_M = -\frac{v^2}{4x} \sqrt{\frac{2p}{x}}$$

$$** 6-12 \quad \rho = \frac{v_0}{\omega_0} \varphi$$

$$** 6-13 \quad \rho = r_0 e^{\frac{k}{v_0} \varphi}$$

$$** 6-14 \quad \varphi = kt; \quad \rho = b + 2a \cos kt$$

轨迹为螺旋线: $\rho = b + 2a \cos \varphi$

$$v = k \sqrt{4a^2 + b^2 + 4ab \cos kt}; \quad a = k^2 \sqrt{16a^2 + b^2 + 8ab \cos kt}$$

$$** 6-15 \quad a_{\max} = \sqrt{16\pi^4 f^4 z_0^2 + \omega^4 r^2}$$

$$** 6-16 \quad a_\rho = b \dot{\varphi}^2 (\tan^2 \gamma \sin^2 \theta - 1) e^{-\tan \gamma (\sin \theta) \varphi}, \text{ 式中 } \tan \theta = \frac{b}{h}$$

$$** 6-17 \quad v_r = 0, \quad v_\theta = \frac{-h\omega}{\sqrt{1 - \left(\frac{h}{2R}\right)^2}}, \quad v_\varphi = R\omega \sqrt{1 - \left(\frac{h}{2R}\right)^2}$$

第七章

$$7-1 \quad x = 0.2 \cos 4t \text{ m}; \quad v = -0.4 \text{ m/s}; \quad a = -2.771 \text{ m/s}^2$$

$$7-2 \quad \varphi = \frac{1}{30} t \text{ rad}, \quad x^2 + (y + 0.8)^2 = 1.5^2$$

$$7-3 \quad v_c = 9.948 \text{ m/s}; \quad \text{轨迹为以半径为 } 0.25 \text{ m 的圆}$$

$$7-4 \quad \omega = \frac{v}{2l}; \quad \alpha = -\frac{v^2}{2l^2}$$

$$7-5 \quad \theta_{OA} = \arctan \frac{\sin \omega_0 t}{\frac{h}{r} - \cos \omega_0 t}$$

$$7-6 \quad (1) \alpha_2 = \frac{5000\pi}{d^2} \text{ rad/s}^2; \quad (2) a = 592.2 \text{ m/s}^2$$

$$7-7 \quad h_1 = 2 \text{ mm}$$

$$7-8 \quad \alpha = \frac{av^2}{2\pi r^3}$$

$$7-9 \quad \omega_2 = 0, \quad \alpha_2 = -\frac{lb\omega^2}{r^2}$$

$$7-10 \quad \varphi = \frac{r_2 \alpha_2}{2l} t^2$$

$$7-11 \quad \omega = \frac{v}{2R \sin \varphi}, \quad v_c = \frac{v}{\sin \varphi}, \quad \text{其中 } \sin \varphi = \frac{1}{2} \sqrt{2 - 2\sqrt{2} \frac{vt}{R} - \left(\frac{vt}{R}\right)^2}$$

$$7-12 \quad \varphi = \frac{\sqrt{3}}{3} \ln \left(\frac{1}{1 - \sqrt{3} \omega_0 t} \right); \quad \omega = \omega_0 e^{\sqrt{3} \varphi}$$

$$7-13 \quad \omega = 2\mathbf{k}, \quad \mathbf{a} = -1.5\mathbf{k}, \quad \mathbf{a}_c = (-388.9\mathbf{i} + 176.8\mathbf{j}) \text{ mm/s}^2$$

$$7-14 \quad \mathbf{v} = (-8\mathbf{i} + 4.8\mathbf{j} - 3.6\mathbf{k}) \text{ m/s}$$

$$\mathbf{a} = (-240\mathbf{i} - 256\mathbf{j} + 192\mathbf{k}) \text{ m/s}^2$$

第八章

$$8-1 \quad x' = v_e t$$

$$y' = a \cos(kt + \beta);$$

$$y' = a \cos \left(\frac{k}{v_e} x' + \beta \right)$$

$$8-2 \quad \text{相对轨迹为圆: } (x' - 40)^2 + y'^2 = 1600$$

$$\text{绝对轨迹为圆: } (x + 40)^2 + y^2 = 1600$$

$$8-3 \quad v_r = 10.06 \text{ m/s}, \quad \angle(\mathbf{v}_r, \mathbf{R}) = 41^\circ 48'$$

$$8-4 \quad v_a = 3.059 \text{ m/s}$$

$$8-5 \quad v_A = \frac{lav}{x^2 + a^2}$$

$$8-6 \quad v_r = 63.62 \text{ mm/s}, \quad \angle(\mathbf{v}_r, \mathbf{v}) = 80^\circ 57'$$

$$8-7 \quad \text{a: } \omega_2 = 1.5 \text{ rad/s};$$

$$\text{b: } \omega_2 = 2 \text{ rad/s}$$

$$8-8 \quad \text{当 } \varphi = 0^\circ \text{ 时, } v = \frac{\sqrt{3}}{3} r\omega, \text{ 向左}$$

$$\text{当 } \varphi = 30^\circ \text{ 时, } v = 0$$

当 $\varphi = 60^\circ$ 时, $v = \frac{\sqrt{3}}{3} r\omega$, 向右

$$8-9 \quad v_C = \frac{av}{2l}$$

$$8-10 \quad v_{AB} = e\omega$$

$$8-11 \quad v_M = 0.529 \text{ m/s}$$

$$8-12 \quad v_r = \frac{\omega\rho\sin\theta}{\cos(\theta-\beta)}$$

$$8-13 \quad v = \frac{1}{\sin\theta} \sqrt{v_1^2 + v_2^2 - 2v_1v_2\cos\theta}$$

$$8-14 \quad v_r = 316.2 \text{ mm/s}, \quad a_r = 500 \text{ mm/s}^2;$$

$$8-15 \quad \mathbf{v}_{AB} = -(37.32\mathbf{i}' + 10\mathbf{j}') \text{ m/s}$$

$$\mathbf{a}_{AB} = -4\mathbf{j}' \text{ m/s}^2$$

$$8-16 \quad v_r = 36.74 \text{ mm/s}, \quad a_r = 30.62 \text{ mm/s}^2$$

$$\omega = 0.5 \text{ rad/s}, \quad \alpha = -0.5 \text{ rad/s}^2$$

$$8-17 \quad v = 0.1 \text{ m/s}, \quad a = 0.346 \text{ m/s}^2$$

$$8-18 \quad v_r = 0.052 \text{ m/s}, \quad a_r = 0.00527 \text{ m/s}^2$$

$$\omega = 0.175 \text{ rad/s}, \quad \alpha = 0.0352 \text{ rad/s}^2$$

$$8-19 \quad v = 0.173 \text{ m/s}, \quad a = 0.05 \text{ m/s}^2$$

$$8-20 \quad \omega_1 = \frac{\omega}{2}, \quad \alpha_1 = \frac{\sqrt{3}}{12} \omega^2$$

$$8-21 \quad v_r = \frac{2}{\sqrt{3}} v_0, \quad a_r = \frac{8\sqrt{3}}{9} \frac{v_0^2}{R}$$

$$8-22 \quad x = 0.1t^2 \text{ m}, \quad y = h - 0.05t^2 \text{ m}; \quad y = h - \frac{x}{2};$$

$$v = 0.1\sqrt{5}t \text{ m/s}, \quad a = 0.1\sqrt{5} \text{ m/s}^2$$

$$8-23 \quad a_A = 0.746 \text{ m/s}^2$$

$$8-24 \quad a_1 = r\omega^2 - \frac{v^2}{r} - 2\omega v$$

$$a_2 = \sqrt{\left(r\omega^2 + \frac{v^2}{r} + 2\omega v\right)^2 + 4r^2\omega^4}$$

$$8-25 \quad a_M = 355.5 \text{ mm/s}^2$$

$$8-26 \quad v_M = 0.173 \text{ m/s}, \quad a_M = 0.35 \text{ m/s}^2$$

$$8-27 \quad v = 0.325 \text{ m/s}, \quad a = 0.657 \text{ m/s}^2$$

$$8-28 \quad a_M = \sqrt{(b + v_r t)^2 \omega^4 + 4\omega^2 v_r^2} \sin\theta$$

第九章

$$9-1 \quad x_C = r\cos\omega_0 t, \quad y_C = r\sin\omega_0 t; \quad \varphi = \omega_0 t$$

- 9-2 $x_A = 0, y_A = \frac{1}{3}gt^2; \varphi = \frac{g}{3r}t^2$
- 9-3 $x_A = (R+r)\cos\frac{at^2}{2}, y_A = (R+r)\sin\frac{at^2}{2};$
 $\varphi_A = \frac{1}{2r}(R+r)at^2$
- 9-4 $\omega = \frac{v\sin^2\theta}{R\cos\theta}$
- 9-5 $v_{BC} = 2.513 \text{ m/s}$
- 9-6 $\omega_{ABD} = 1.072 \text{ rad/s}; v_D = 0.254 \text{ m/s}$
- 9-7 $\omega_{OD} = 10\sqrt{3} \text{ rad/s}, \omega_{DE} = \frac{10}{3}\sqrt{3} \text{ rad/s}$
- 9-8 $v_F = 0.462 \text{ m/s}; \omega_{EF} = 1.333 \text{ rad/s}$
- 9-9 当 $\varphi = 0^\circ, 180^\circ$ 时, $v_{DE} = 4 \text{ m/s}$
 当 $\varphi = 90^\circ, 270^\circ$ 时, $v_{DE} = 0$
- 9-10 $\omega_{OB} = 3.75 \text{ rad/s}, \omega_I = 6 \text{ rad/s}$
- 9-11 $n = 10\,800 \text{ r/min}$
- 9-12 $v_F = 1.295 \text{ m/s}$
- 9-13 $\omega_{O_1} = \frac{(b_1 + b_2)r_2 v}{a_1 b_2 r_2 - a_2 b_1 r_1}$
- 9-14 $a_C = 2r\omega_O^2$
- 9-15 $v_O = \frac{R}{R-r}v; a_O = \frac{R}{R-r}a$
- 9-16 $v_B = 2 \text{ m/s}, v_C = 2.828 \text{ m/s};$
 $a_B = 8 \text{ m/s}^2, a_C = 11.31 \text{ m/s}^2$
- 9-17 $v_M = 0.098 \text{ m/s}, a_M = 0.013 \text{ m/s}^2$
- 9-18 $a_n = 2r\omega_O^2, a_t = r(\sqrt{3}\omega_O^2 - 2\alpha_O)$
- 9-19 $v_C = \frac{3}{2}r\omega_O; a_C = \frac{\sqrt{3}}{12}r\omega_O^2$
- 9-20 $\omega = -1 \text{ rad/s}, \alpha = 2 \text{ rad/s}^2; v_C = 0.05 \text{ m/s} \uparrow, a_C = 0.1 \text{ m/s}^2 \downarrow;$
 $v_D = 0.2 \text{ m/s} \uparrow, a_D = 0.427 \text{ m/s}^2 \searrow; v_E = 0.1 \text{ m/s} \downarrow, a_E = 0.25 \text{ m/s}^2 \swarrow$
- 9-21 $a_A = 2.423 \text{ m/s}^2, a_A = 5.233 \text{ m/s}^2$
- 9-22 $\omega = 2 \text{ rad/s}, \alpha = 2 \text{ rad/s}^2$
- 9-23 $\omega_{O_1 C} = 6.186 \text{ rad/s}, \alpha_{O_1 C} = 78.17 \text{ rad/s}^2$
- 9-24 $\omega_{O_1 A} = 0.2 \text{ rad/s}, \alpha_{O_1 A} = 0.0462 \text{ rad/s}^2$
- 9-25 $v_{DB} = 1.155 l\omega_O, a_{DB} = 2.222 l\omega_O^2$
- 9-26 $v_{AB} = v \tan \theta, v_r = v \tan \theta \tan \frac{\theta}{2},$

$$a_{AB} = a \tan \theta + \frac{v^2}{R \cos \theta} \left(1 + \tan \theta \tan \frac{\theta}{2} \right)^2$$

$$\cdot 9-27 \quad v_{CD} = \frac{0.2\sqrt{3}}{3} \text{ m/s}, \quad a_{CD} = \frac{2}{3} \text{ m/s}^2$$

$$9-28 \quad (1) \quad v_c = 0.4 \text{ m/s}, \quad v_r = 0.2 \text{ m/s};$$

$$(2) \quad a_c = 0.159 \text{ m/s}^2, \quad a_r = 0.139 \text{ m/s}^2$$

$$9-29 \quad v_E = \frac{v}{2}, \quad a_E = \frac{7}{8\sqrt{3}} \frac{v^2}{b}; \quad \omega = \frac{3}{4} \frac{v}{b}, \quad \alpha = \frac{3\sqrt{3}}{8} \frac{v^2}{b^2}$$

$$9-30 \quad v_B = 1.029 \text{ m/s}, \quad a_B = -5.237 \text{ m/s}^2$$

$$\cdot 9-31 \quad v_C = 6.865 r\omega_0, \quad a_C = 16.14 r\omega_0^2$$

$$\cdot 9-32 \quad \varphi = 0^\circ \text{ 时}, v = 0.15 \text{ m/s}; \quad \varphi = 45^\circ \text{ 时}, v = 0.49 \text{ m/s};$$

$$\varphi = 90^\circ \text{ 时}, v = 0.588 \text{ m/s}$$

$$\cdot 9-33 \quad v_3 = v_1 \frac{ay}{x^2} - v_2 \frac{a-x}{x}; \quad \omega_4 = \frac{v_1 y - v_2 x}{x^2 + y^2}$$

$$\cdot 9-34 \quad v_{r1} = 0.6 \text{ m/s}, \quad v_{r2} = 0.9 \text{ m/s}, \quad v_M = 0.459 \text{ m/s}$$

$$a_{r1} = 2.816 \text{ m/s}^2, \quad a_{r2} = 4.592 \text{ m/s}^2, \quad a_M = 2.5 \text{ m/s}^2$$

$$\cdot 9-35 \quad \text{a } v_C = r\omega \leftarrow, \quad \text{b } v_C = \frac{\sqrt{3}}{3} r\omega \leftarrow$$

$$\text{c } v_C = \sqrt{3} r\omega \leftarrow, \quad \text{d } v_C = \frac{4}{3} r\omega \leftarrow$$

$$\cdot 9-36 \quad \text{a } a_C = \frac{5\sqrt{3}}{12} r\omega^2 \leftarrow, \quad \text{b } a_C = \left(1 + \frac{2\sqrt{3}}{9} \right) r\omega^2 \leftarrow$$

$$\text{c } a_C = 4r\omega^2 \rightarrow, \quad \text{d } a_C = \frac{4\sqrt{3}}{9} r\omega^2 \leftarrow$$

第十章

$$10-1 \quad n_{\max} = \frac{30}{\pi} \sqrt{\frac{fg}{r}} \text{ r/min}$$

$$10-2 \quad t = \sqrt{\frac{h}{g} \frac{m_1 + m_2}{m_1 - m_2}}$$

$$10-3 \quad (1) \quad F_{N\max} = m(g + e\omega^2); \quad (2) \quad \omega_{\max} = \sqrt{\frac{g}{e}}$$

$$10-4 \quad n = 67 \text{ r/min}$$

$$10-5 \quad h = 78.4 \text{ mm}$$

$$10-6 \quad F = m \left(g + \frac{l^2 v_0^2}{x^3} \right) \sqrt{1 + \left(\frac{l}{x} \right)^2}$$

$$\cdot 10-7 \quad F_N = 0.284 \text{ N}$$

$$\cdot 10-8 \quad F = \frac{\sqrt{3}}{2} mg$$

10-9 $F = 488.56 \text{ kN}$

10-10 时间 $t = 2.02 \text{ s}$; 路程 $s = 7.07 \text{ m}$

10-11 椭圆 $\frac{x^2}{x_0^2} + \frac{k}{m} \frac{y^2}{v_0^2} = 1$

10-12 $x = \frac{v_0}{k}(1 - e^{-kt}), y = h - \frac{g}{k}t + \frac{g}{k^2}(1 - e^{-kt});$

轨迹为: $y = h - \frac{g}{k^2} \ln \frac{v_0}{v_0 - kx} + \frac{gx}{kv_0}$

10-13 圆, 半径为 $\frac{mv_0}{eH}$

第十一章

11-1 $f = 0.17$

11-2 $F = 1068 \text{ N}$

11-3 向左移动 0.266 m

11-4 向左移动 $\frac{a-b}{4}$

11-5 $\Delta v = 0.246 \text{ m/s}$

11-6 椭圆 $4x^2 + y^2 = l^2$

11-7 $p = \frac{l\omega}{2}(5m_1 + 4m_2)$, 方向与曲柄垂直且向上

11-8 $a = \frac{m_2 b - f(m_1 + m_2)g}{m_1 + m_2}$

* 11-9 $a_A = \frac{\sin \theta \cos \theta}{\sin^2 \theta + 3} g; F_N = \frac{12m_B g}{\sin^2 \theta + 3}$

11-10 $\ddot{x} + \frac{k}{m+m_1}x = \frac{m_1 l \omega^2}{m+m_1} \sin \varphi$

11-11 $x_C = \frac{m_3 l}{2(m_1 + m_2 + m_3)} + \frac{m_1 + 2m_2 + 2m_3}{2(m_1 + m_2 + m_3)} l \cos \omega t,$

$$y_C = \frac{m_1 + 2m_2}{2(m_1 + m_2 + m_3)} l \sin \omega t;$$

$$F_{x\max} = \frac{1}{2}(m_1 + 2m_2 + 2m_3) l \omega^2$$

11-12 $F_x = -(m_1 + m_2) e \omega^2 \cos \omega t, F_y = -m_2 e \omega^2 \sin \omega t$

11-13 $F_x = -138.6 \text{ N}, F_y = 0$

11-14 $F_x = \rho q v (v_1 + v_2 \cos \theta) \text{ N}$

11-15 $F_x = 30 \text{ N}$

11-16 $F_x = 67.82 \text{ N}$

第十二章

12-1 $L_O = 2ab\omega m \cos^3 \omega t$

$$12-2 \quad (a) L_O = 18 \text{ kg}\cdot\text{m}^2/\text{s}; \quad (b) L_O = 20 \text{ kg}\cdot\text{m}^2/\text{s}; \\ (c) L_O = 16 \text{ kg}\cdot\text{m}^2/\text{s}$$

$$12-3 \quad (1) p = \frac{R+e}{R}mv_A, \quad L_B = [J_A - me^2 + m(R+e)^2]\frac{v_A}{R}; \\ (2) p = m(v_A + e\omega), \quad L_B = (J_A + mRe)\omega + m(R+e)v_A$$

$$12-4 \quad \omega = \frac{2m_2art}{m_1R^2 + 2m_2r^2}; \quad \alpha = \frac{2m_2ar}{m_1R^2 + 2m_2r^2}$$

$$12-5 \quad \omega = \frac{ml(1 - \cos \varphi)v_0}{J + m(l^2 + r^2 + 2lr\cos \varphi)}$$

$$12-6 \quad (1) \omega = \frac{J_1\omega_0}{J_1 + J_2}; \quad (2) M_t = \frac{J_1J_2\omega_0}{(J_1 + J_2)t}$$

$$12-7 \quad \alpha_1 = \frac{2(R_2M - R_1M')}{(m_1 + m_2)R_1R_2}$$

$$12-8 \quad J = 1060 \text{ kg}\cdot\text{m}^2; \quad M_t = 6.024 \text{ N}\cdot\text{m}$$

$$12-9 \quad t = \frac{1}{k}J \ln 2; \quad n = \frac{J\omega_0}{4\pi k}$$

$$12-10 \quad M_x = 365.4 \text{ N}\cdot\text{m}$$

$$12-11 \quad t = \frac{r_1\omega}{2fg\left(1 + \frac{m_1}{m_2}\right)}$$

$$12-12 \quad J_{AB} = mgh \left(\frac{T^2}{4\pi^2} - \frac{h}{g} \right)$$

$$12-13 \quad \rho = 90 \text{ mm}$$

$$12-14 \quad a_A = \frac{m_1g(r+R)^2}{m_1(R+r)^2 + m_2(\rho^2 + R^2)}$$

$$12-15 \quad (1) x_C = 0, \quad y_C = 0.4\pi t - \frac{1}{2}gt^2, \quad \varphi = \pi t;$$

$$(2) t = 2 \text{ s}, \quad \varphi = \pi t = 2\pi \text{ rad}, \quad \text{杆在水平位置}, y_A = y_B = y_C = -17.1 \text{ m};$$

$$(3) F_T = 3.95 \text{ N}$$

$$12-16 \quad v = \frac{2}{3}\sqrt{3gh}; \quad F_T = \frac{1}{3}mg$$

$$12-17 \quad \alpha = \frac{3g}{2l}\cos \varphi; \quad \omega = \sqrt{\frac{3g}{l}(\sin \varphi_0 - \sin \varphi)}; \quad \varphi_1 = \arcsin \left(\frac{2}{3}\sin \varphi_0 \right)$$

$$12-18 \quad a = \frac{F - f(m_1 + m_2)g}{m_1 + \frac{m_2}{3}}$$

$$12-19 \quad a = \frac{4}{7}g\sin \theta; \quad F = -\frac{1}{7}mg\sin \theta$$

$$12-20 \quad t = \frac{v_0 - \omega_0 r}{3fg}; \quad v = \frac{2v_0 + r\omega_0}{3}$$

$$12-21 \quad a_C = 0.355g$$

$$12-22 \quad a_A = \frac{7}{23}g; \quad a_B = \frac{21}{46}g$$

$$12-23 \quad (1) a = \frac{4}{5}g; \quad (2) M > 2mgr$$

$$12-24 \quad (1) F_{AB} = 7.35 \text{ N, 向左}; \quad F_{Dx} = 66.15 \text{ N}, \quad F_{Dy} = 29.4 \text{ N};$$

$$(2) a = 3g; \quad F_{Dx} = 88.2 \text{ N}, \quad F_{Dy} = 29.4 \text{ N}$$

第十三章

$$13-1 \quad W = 109.7 \text{ J}$$

$$13-2 \quad W = 6.29 \text{ J}$$

$$13-3 \quad T = \frac{1}{2}(3m_1 + 2m)v^2$$

$$13-4 \quad T = \frac{1}{6}ml^2\omega^2\sin^2\theta$$

$$13-5 \quad v = 8.1 \text{ m/s}$$

$$13-6 \quad n = 412 \text{ r/min}$$

$$13-7 \quad v_A = \sqrt{\frac{3}{m}[M\theta - mgl(1 - \cos\theta)]}$$

$$13-8 \quad v = 2.512 \text{ m/s}$$

$$13-9 \quad v_2 = \sqrt{\frac{4gh(m_2 - 2m_1 + m_4)}{8m_1 + 2m_2 + 4m_3 + 3m_4}}$$

$$13-10 \quad x_2 : x_1 = (2m_2 + m_1) : (2m_2 + 3m_1)$$

$$13-11 \quad (1) \text{ 圆盘的角速度 } \omega_B = 0, \text{ 连杆的角速度 } \omega_{AB} = 4.95 \text{ rad/s};$$

$$(2) \delta_{\max} = 87.1 \text{ mm}$$

$$13-12 \quad v = \sqrt{\frac{2(M - m_1 gr \sin\theta)}{r(m_1 + m_2)}} \text{ s}; \quad a = \frac{M - m_1 gr \sin\theta}{r(m_1 + m_2)}$$

$$13-13 \quad \omega = \frac{2}{R+r} \sqrt{\frac{3M\varphi}{9m_1 + 2m_2}}; \quad \alpha = \frac{6M}{(R+r)^2(9m_1 + 2m_2)}$$

$$13-14 \quad \omega_a = \frac{2.47}{\sqrt{a}} \text{ rad/s}; \quad \omega_b = \frac{3.12}{\sqrt{a}} \text{ rad/s}$$

$$13-15 \quad b = \frac{\sqrt{3}}{6}l$$

$$13-16 \quad a_A = \frac{3m_1g}{4m_1 + 9m_2}$$

$$13-17 \quad M_{\pm} = 188.2 \text{ N}\cdot\text{m}; \quad M_{\text{电}} = 42.4 \text{ N}\cdot\text{m}; \quad P_{\text{电}} = 6.31 \text{ kW}$$

$$13-18 \quad P = 0.369 \text{ kW}$$

综合问题

$$\text{综-1} \quad v = 2\cos\varphi \sqrt{R\left(g + \frac{kR}{m}\right)};$$

$$F_N = 2kR \sin^2 \varphi - mg \cos 2\varphi - 4(mg + kR) \cos^2 \varphi$$

综-2 $F_n = 20g(2 - 3\cos \varphi), F_t = 0$; 当 $\varphi = \pi$ 时, $F_{\max} = 980 \text{ N}$ (拉);

当 $\varphi = \arccos \frac{2}{3} = 48^\circ 11'$ 时, $F_{\min} = 0$

综-3 (1) 小球运动方程以极坐标表示为: $r = R - vt, \varphi = \frac{v_0 t}{R - vt}$;

(2) $F = \frac{mv_0^2 R^2}{(R - vt)^3}$

综-4 (1) $a = a_t = \frac{1}{2}g = 4.9 \text{ m/s}^2, F_A = 72 \text{ N}, F_B = 268 \text{ N}$;

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

综-5 $a_B = \frac{m_1 g \sin 2\theta}{2(m_2 + m_1 \sin^2 \theta)}$

综-6 $F = \frac{M(m_1 + 2m_2)}{2R(m_1 + m_2)}$

综-7 $\omega_B = \frac{J\omega}{J + mR^2}, v_B = \sqrt{\frac{2mgR - J\omega^2 \left[\frac{J^2}{(J + mR^2)^2} - 1 \right]}{m}}$;

$\omega_C = \omega, v_C = \sqrt{4gR}$

综-8 $F = 9.8 \text{ N}$

综-9 $a_{BC} = -r\omega^2 \cos \omega t; F_{ax} = -r\omega^2 \left(\frac{m_1}{2} + m_2 \right) \cos \omega t,$

$F_{ay} = m_1 g - \frac{1}{2} m_1 r\omega^2 \sin \omega t;$

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

综-10 $v_r = \sqrt{\frac{8}{3}gr}, F_N = \frac{11}{3}mg$

综-11 $\omega = \sqrt{\frac{3g}{2l}}; x_C^2 + 3ly_C + 3l^2 = 0$

综-12 $a = \frac{m_1 \sin \theta - m_2}{2m_1 + m_2} g; F = \frac{3m_1 m_2 + (2m_1 m_2 + m_1^2) \sin \theta}{2(2m_1 + m_2)} g$

综-13 $a_A = \frac{1}{6}g; F = \frac{4}{3}mg; F_{Kx} = 0, F_{Ky} = 4.5mg, M_K = 13.5mgR$

综-14 (1) $\alpha = \frac{M - mgR \sin \theta}{2mR^2}$; (2) $F_x = \frac{1}{8R}(6M \cos \theta + mgR \sin 2\theta)$

综-15 $\omega = \sqrt{\frac{3m_1 + 6m_2}{m_1 + 3m_2} \frac{g}{l} \sin \theta}; \alpha = \frac{3m_1 + 6m_2}{m_1 + 3m_2} \frac{g}{2l} \cos \theta$

综-16 $a = \frac{m_2 \sin 2\theta}{3m_1 + m_2 + 2m_2 \sin^2 \theta} g$

综-17 $F_N = \frac{7}{3}mg \cos \theta; F = \frac{1}{3}mg \sin \theta$

$$\text{综-18 } \omega = \sqrt{\frac{3g}{l} (1 - \sin \varphi)}; \quad \alpha = \frac{3g}{2l} \cos \varphi;$$

$$F_A = \frac{9}{4} mg \cos \varphi \left(\sin \varphi - \frac{2}{3} \right),$$

$$F_B = \frac{mg}{4} \left[1 + 9 \sin \varphi \left(\sin \varphi - \frac{2}{3} \right) \right]$$

$$\text{综-19 (1) } \omega = \sqrt{\frac{3g}{l} (1 - \cos \theta)}, \quad \alpha = \frac{3g}{2l} \sin \theta,$$

$$F_{Bx} = \frac{3}{4} mg \sin \theta (3 \cos \theta - 2),$$

$$F_{By} = mg - \frac{3}{4} mg (3 \sin^2 \theta + 2 \cos \theta - 2);$$

$$(2) \theta_1 = \arccos \frac{2}{3};$$

$$(3) v_C = \frac{1}{3} \sqrt{7gl}, \quad \omega = \sqrt{\frac{8g}{3l}}$$

$$\text{综-20 (1) } \Delta p = \frac{3Mt}{2l}; \quad \Delta L = Mt; \quad \Delta T = \frac{3}{2} \frac{M^2 t^2}{ml^2};$$

$$(2) F_{Cx} = F_{Dx} = \frac{3}{4} \frac{M}{l}, \quad F_{Cy} = F_{Dy} = \frac{9}{4} \frac{M^2 t^2}{ml^3}$$

第十四章

$$14-1 (1) a \leq 2.91 \text{ m/s}^2; \quad (2) \frac{h}{d} \geq 5 \text{ 时先倾倒}$$

$$14-2 F_{NA} = m \frac{bg - ba}{c + b}, \quad F_{NB} = m \frac{cg + ha}{c + b}$$

$$a = \frac{(b-c)g}{2h} \text{ 时, } F_{NA} = F_{NB}$$

$$14-3 m_3 = 50 \text{ kg}, \quad a = 2.45 \text{ m/s}^2$$

$$14-4 \omega^2 = g \frac{2m_1 + m_2}{2m_1(a + l \sin \varphi)} \tan \varphi$$

$$14-5 (J + mr^2 \sin^2 \varphi) \ddot{\varphi} + mr^2 \dot{\varphi}^2 \cos \varphi \sin \varphi = M$$

$$14-6 \alpha = 47 \text{ rad/s}^2; \quad F_{Ax} = -95.34 \text{ N}, \quad F_{Ay} = 137.72 \text{ N}$$

$$14-7 F_n = \rho r^2 \omega^2 \sin \theta \text{ (圆环法向)},$$

$$F_t = \rho r^2 \omega^2 (1 + \cos \theta) \text{ (圆环切向)}; \quad M_B = \rho r^3 \omega^2 (1 + \cos \theta)$$

$$14-8 x = b e^{\frac{a}{\epsilon} y}$$

$$14-9 (1) \omega = \sqrt{\frac{k(\varphi - \varphi_0)}{ml^2 \sin 2\varphi}};$$

$$(2) F_{Bx} = 0, \quad F_{By} = -\frac{ml^2 \omega^2 \sin 2\varphi}{2b};$$

$$F_{Ax} = 0, \quad F_{Ay} = \frac{ml^2 \omega^2 \sin 2\varphi}{2b}, \quad F_{Az} = 2 mg$$

$$14-10 \quad \alpha = \frac{m_2 r - m_1 R}{J + m_1 R^2 + m_2 r^2} g; \text{轴 } O \text{ 附加动反力}$$

$$F'_{Ox} = 0, \quad F'_{Oy} = \frac{-g(m_2 r - m_1 R)^2}{J_0 + m_1 R^2 + m_2 r^2}$$

$$14-11 \quad F_{Cx} = 0, \quad F_{Cy} = \frac{3m_1 + m_2}{2m_1 + m_2} m_2 g, \quad M_C = \frac{3m_1 + m_2}{2m_1 + m_2} m_2 g a$$

$$14-12 \quad a = \frac{(iM - mgR)R}{mR^2 + J_1 i^2 + J_2}$$

$$14-13 \quad F_B = 9.8 \text{ kN}$$

$$14-14 \quad \omega = \frac{\sqrt{2ra}}{\rho}$$

$$14-15 \quad M = \frac{\sqrt{3}}{4} (m_1 + 2m_2) gr - \frac{\sqrt{3}}{4} m_2 r^2 \omega^2;$$

$$F_{Ox} = -\frac{\sqrt{3}}{4} m_1 r \omega^2;$$

$$F_{Oy} = (m_1 + m_2)g - (m_1 + 2m_2) \frac{r\omega^2}{4}$$

$$14-16 \quad F_{Ox} = \frac{11}{4} mr\omega_0^2 + \frac{3\sqrt{3}}{2} mg, \quad F_{Oy} = \frac{3\sqrt{3}}{4} mr\omega_0^2 + \frac{5}{2} mg;$$

$$M = \frac{3\sqrt{3}}{4} mr^2 \omega_0^2 + 2mgr$$

$$14-17 \quad a = \frac{8}{11} \frac{F}{m}$$

$$14-18 \quad F_{NB} = \frac{2}{9} m\omega_0^2 r + 2mg + \frac{\sqrt{3}F}{3}; \quad M_O = \frac{2\sqrt{3}}{3} m\omega_0^2 r^2 + Fr$$

$$14-19 \quad F_{NA} = -F_{NB} = 74 \text{ N}$$

$$14-20 \quad y_B = 0, \quad z_B = -120 \text{ mm}; \quad y_C = 0, \quad z_C = 60 \text{ mm}$$

第十五章

$$15-1 \quad F_N = \frac{1}{2} F \tan \theta$$

$$15-2 \quad F_N = \pi \frac{M}{h} \cot \theta$$

$$15-3 \quad M = \frac{1}{2} Fr$$

$$15-4 \quad F_N = \frac{F e(d+c)}{2bc}$$

$$15-5 \quad F_2 = \frac{F_1 l}{a \cos^2 \varphi}$$

$$15-6 \quad F = \frac{M}{a} \cot 2\theta$$

$$15-7 \quad M = 450 \frac{\sin \theta (1 - \cos \theta)}{\cos^3 \theta} \text{N} \cdot \text{m}$$

$$15-8 \quad AC = x = a + \frac{F}{k} \left(\frac{l}{b} \right)^2$$

$$15-9 \quad \tan \varphi = \frac{P_1}{2(P_1 + P_2)} \cot \theta$$

$$15-10 \quad \frac{F_1}{F_2} = \frac{2l_1 \sin \theta}{l_2 + l_1 (1 - 2\sin^2 \theta)}$$

$$15-11 \quad \text{曲线方程为: } \frac{x^2}{4l^2} + \frac{y^2}{l^2} = 1$$

$$15-12 \quad F = \frac{Pl}{\sqrt{2a}} \tan \theta \sqrt{1 + \sin \theta}$$

$$15-13 \quad M = 2RF, \quad F_s = F$$

$$15-14 \quad \delta = -\frac{ql}{6k_1}, \quad \varphi = \frac{Pl}{2k_2}$$

$$15-15 \quad F_3 = P$$

$$15-16 \quad F_A = -2450 \text{ N}, \quad F_B = 14700 \text{ N}, \quad F_E = 2450 \text{ N}$$