Answers to Selected Even-Numbered Problems

Please note that answers are not provided for the following type of even-numbered problems:

- Concept Problems.
- Computer Problems.
- Design Problems.

For Concept and Computer problems, please consult the solutions manual.

Chapter 1

1.2 $(r_{B/A})_\ell = 3.883\,\text{ft}$

1.4 $\vec{r}_{B/A}\big|_{xy\text{ system}} = (4.000\,\hat{\imath} - 1.000\,\hat{\jmath})\,\text{ft}$

$\vec{r}_{B/A}\big|_{pq\text{ system}} = (3.313\,\hat{u}_p - 2.455\,\hat{u}_q)\,\text{ft}$

$\big|\vec{r}_{B/A}\big|_{xy\text{ system}} = \big|\vec{r}_{B/A}\big|_{pq\text{ system}} = 4.123\,\text{ft}$

1.6 $\vec{v} = (79.68\,\hat{\imath} + 7.190\,\hat{\jmath})\,\text{ft/s}$

1.8 $\theta = 3.229\,\text{rad}$

$\phi = 0.087\,31\,\text{rad}$

1.10 $v_r = 504.6\,\text{ft/s}$ and $v_\theta = -353.3\,\text{ft/s}$

1.12 $\phi = 101.1°$

1.14 $x_{P2} = -0.7679\,\text{ft}$ and $y_{P2} = 5.330\,\text{ft}$

1.16 $\vec{v}_A = -(20.02\,\hat{\imath} + 12.81\,\hat{\jmath})\,\text{ft/s}$ and $\vec{a}_A = (-1.414\,\hat{\imath} + 4.243\,\hat{\jmath})\,\text{ft/s}^2$

1.18 $r = 26.36\,\text{mm}$

1.20 $[I_{xx}] = [I_{yy}] = [I_{zz}] = ML^2$

Units of I_{xx}, I_{yy}, and I_{zz} in the SI system: $\text{kg}\cdot\text{m}^2$,
Units of I_{xx}, I_{yy}, and I_{zz} in the U.S. Customary system: $\text{slug}\cdot\text{ft}^2 = \text{lb}\cdot\text{s}^2\cdot\text{ft}$.

1.22 Concept problem.

1.24 the units of E are $\text{kg}/(\text{m}\cdot\text{s}^2)$.

Chapter 2

2.2 Concept Problem

2.4 Concept Problem

2.6 $\Delta\vec{r}_1 = 8.747\,\hat{u}_r\text{ m}$ and $\Delta\vec{r}_2 = 13.73\,\hat{u}_r\text{ m}$

$(\vec{v}_{\text{avg}})_1 = 5.467\,\hat{u}_r\text{ m/s}$ and $(\vec{v}_{\text{avg}})_2 = 8.579\,\hat{u}_r\text{ m/s}$

2.8 $\vec{v} = (-154.0\,\hat{\imath} + 266.7\,\hat{\jmath})\text{ ft/s}$

2.10 $\vec{v} = (145.4\,\hat{\imath} + 69.81\,\hat{\jmath})\text{ ft/s}$

2.12 $\Delta\vec{v}_1 = -(0.4623\,\hat{\imath} + 0.08155\,\hat{\jmath})\text{ m/s}$

$\Delta\vec{v}_2 = -(0.002550\,\hat{\imath} + 0.0004499\,\hat{\jmath})\text{ m/s}$

2.14 $\theta_1 = 12.21^\circ$ and $\theta_2 = -17.30^\circ$

$\phi_1 = 102.2^\circ$ and $\phi_2 = 72.70^\circ$

2.16 $\phi(x) = \cos^{-1}\left(\dfrac{3+4x}{\sqrt{10+24x+16x^2}}\right)$

2.18 $\vec{a}_{\text{avg}} = (-0.04588\,\hat{\imath} + 3.886\,\hat{\jmath})\text{ ft/s}^2$

$\vec{a}_{\text{avg}} - \vec{a}(5\text{ s}) = (-0.001154\,\hat{\imath} - 0.003175\,\hat{\jmath})\text{ ft/s}^2$

2.20 $\Delta\vec{r} = \vec{0}$

$\vec{v}_{\text{avg}} = \vec{0}$

$d = 1.394\text{ ft}$

$v_{\text{avg}} = 0.3485\text{ ft/s}$

2.22 Computer Problem

2.24 $v_{\max} = 2v_0 = 58.67\text{ ft/s}$ and $v_{\min} = 0\text{ ft/s}$

$y_{v_{\min}} = 0\text{ ft}$ and $y_{v_{\max}} = 2R = 2.300\text{ ft}$

$\vec{a}_{v_{\min}} = \dfrac{v_0^2}{R}\,\hat{\jmath} = (748.2\text{ ft/s}^2)\,\hat{\jmath}$ and $\vec{a}_{v_{\max}} = -\dfrac{v_0^2}{R}\,\hat{\jmath} = (-748.2\text{ ft/s}^2)\,\hat{\jmath}$

2.26 $\ddot{x} = \dfrac{8v_0^2a^3}{(y^2+4a^2)^2}$

$\ddot{y} = \dfrac{-4v_0^2a^2y}{(y^2+4a^2)^2}$

2.28 $\vec{v} = (203.2\,\hat{\imath} + 117.3\,\hat{\jmath})\text{ ft/s}$

$\vec{a} = (-27.53\,\hat{\imath} + 47.69\,\hat{\jmath})\text{ ft/s}^2$

2.30 $v_{\max} = 80.82\text{ ft/s}$

2.32 $\vec{v} = (51.32\,\hat{\imath} - 1.046\,\hat{\jmath})\text{ ft/s}$

$\vec{a} = -(0.3873\,\hat{\imath} + 19.00\,\hat{\jmath})\text{ ft/s}^2$

2.34 $v = \omega\sqrt{d^2 - x^2}\sqrt{1 + h^2\left(\frac{x}{d^2} - \frac{x^3}{d^4}\right)^2}$

$v = 0.5236\,\text{ft/s}, \quad v = 0.4554\,\text{ft/s}, \quad \text{and} \quad v = 0$

2.36 $\vec{v}_A = -(72.00\,\hat{\imath} + 96.00\,\hat{\jmath})\,\text{ft/s}$

$\vec{a}_A = (460.8\,\hat{\imath} - 345.6\,\hat{\jmath})\,\text{ft/s}^2$

2.38 Computer Problem

2.40 $t_{\text{braking}} = 7.854\,\text{s}$

2.42 $|a|_{\text{max}} = 3.600\,\text{m/s}^2$

$\left(t_{|a_{\text{max}}|}\right)_1 = 3.927\,\text{s} \quad \text{and} \quad \left(t_{|a_{\text{max}}|}\right)_2 = 11.78\,\text{s}$

$\left(s_{|a_{\text{max}}|}\right)_1 = 12.84\,\text{m} \quad \text{and} \quad \left(s_{|a_{\text{max}}|}\right)_2 = 128.5\,\text{m}$

2.44 Largest distance traveled in 1 s is $d = 0.2667\,\text{m}$, corresponding to $a = \beta_1\sqrt{t}$

2.46 $v(0) = -0.080\,00\,\text{ft/s}$

2.48 $v_0 = 10.10\,\text{m/s}$

2.50 $a_c = 22.36\,g$

2.52 $t_{\text{stop}} = 2.880\,\text{s}$

2.54 $\eta = 98.10\,\text{s}^{-1}$

2.56 $\dot{x} = \big\{7.000\sin[(1.000\,\text{rad/s})t] + 10.50\cos[(0.5000\,\text{rad/s})t] - 10.50\big\}\,\text{m/s}$

$x = \big\{7.000 - 7.000\cos[(1.000\,\text{rad/s})t] + 21.00\sin[(0.5000\,\text{rad/s})t] - (10.50\,\text{s}^{-1})t\big\}\,\text{m/s}^2$

2.58 $t_{\text{stop}} = 0.2233\,\text{s}$

2.60 $v_{\text{term}} = 4.998\,\text{m/s}$

2.62 $|v|_{\text{max}} = 1.128\,\text{m/s}$

$s_{|v|_{\text{max}}} = 0.1250\,\text{m} \quad \text{and} \quad s_{|v|_{\text{max}}} = -0.1250\,\text{m}$

2.64 $v(t) = \frac{mg}{C_d}\left(1 - e^{-C_d t/m}\right)$

$v_{\text{term}} = \frac{mg}{C_d}$

2.66 $v_f = 3.563\,\text{m/s}$

2.68 Computer Problem

2.70 $s_{\text{wet}} = 26.31\,\text{m}$

$$\frac{(s_{\text{wet}} - s_{\text{dry}})}{s_{\text{dry}}}(100\%) = 65.21\%$$

2.72 $\dot{\theta}(\theta) = \pm\sqrt{\dot{\theta}_0^2 + 2\frac{g}{L}\big(\cos\theta - \cos\theta_0\big)}$

2.74 $\dot{\theta}_{\text{min}} = 4.930\,\text{rad/s}$

2.76 $\dot{x} = \pm\sqrt{v_0^2 + 2\left(g + \frac{kL_0}{m}\right)(x - x_0) - \frac{k}{m}\big(x^2 - x_0^2\big)}$

2.78 $t_{x_{\text{max}}} = 0.2433\,\text{s}$

2.80 **(a)** $\dot{r} = -\sqrt{2G\,(m_A + m_B)}\sqrt{\frac{r_0 - r}{r r_0}}$

(b) (i) $\dot{r} = -5.980 \times 10^{-5}\,\text{ft/s}$ and (ii) $\dot{r} \to -\infty$

2.82 Concept Problem

2.84 $d = 186.4\,\text{ft}$

2.86 $\alpha_s = \frac{a_p}{r} + \frac{h v_p^2}{2\pi r^3}$

$\alpha_s\big|_{r=r_1} = 1.442\,\text{rad/s}^2$ and $\alpha_s\big|_{r=r_2} = 3.631\,\text{rad/s}^2$

2.88 $v = v_0 + a_c(t - t_0)$

$s = s_0 + v_0(t - t_0) + \frac{1}{2}a_c(t - t_0)^2$

2.90 $v_{\text{min}} = 113.5\,\text{ft/s}$

2.92 $t_i = 3.497\,\text{s}$

$\vec{v}_B = (33.33\,\hat{\imath} - 34.31\,\hat{\jmath})\,\text{m/s}$

2.94 $R = 5.047\,\text{m}$

2.96 $t_{\text{flight}} = 6.263\,\text{s}$

$\vec{r}_{\text{land}} = (281.8\,\hat{\imath} - 4.500\,\hat{\jmath})\,\text{m}$

2.98 $d = 24.09\,\text{m}$

2.100 **(a)** $\theta_{R_{\text{max}}} = \frac{\pi}{4}\,\text{rad} = 45^\circ$

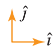
(b) $R_{\text{max}} = 233.5\%$ of the actual maximum range

(c) $t_{R_{\text{max}}} = 119.5\,\text{s}$

2.102 $\theta_1 = \frac{1}{2}\sin^{-1}(gR/v_0^2)$ and $\theta_2 = 90^\circ - \frac{1}{2}\sin^{-1}(gR/v_0^2)$

$\theta_1 = 24.86^\circ$ and $\theta_2 = 65.14^\circ$

2.104 $(v_0)_{\text{min}} = 50.75\,\text{ft/s}$

2.106 $\vec{v}_{\text{initial}} = (5.920\,\hat{\imath} + 7.786\,\hat{\jmath})\,\text{m/s}.$ 

$$\left.\frac{dy}{dx}\right|_{x=x_B} = -0.2244$$

2.108 $h_{\text{max}} = \dfrac{v_0^2 \sin^2\beta}{2g\cos\theta}$

2.110 Computer Problem

2.112 $t_{f_{R_{\text{max}}}} = 5.211\,\text{s}$

$R_{\text{max}} = 437.1\,\text{ft}$ and $\theta_{R_{\text{max}}} = 45.66^\circ$

2.114 $t_{\text{max}} = 3.000\,\text{s}$

$H_{\text{max}} = 49.21\,\text{m}$

percent increase in height with no air resistance $= 2.363\%$

2.116 Computer Problem

2.118 **(a)** $\vec{a}\cdot\vec{b} = 1\cdot -6 + 2\cdot 3 + 3\cdot 0 = 0$

(b) $\vec{a}\times\left(\vec{a}\times\vec{b}\right) = \left(84\,\hat{\imath} - 42\,\hat{\jmath} + 0\,\hat{k}\right)$

(c) they are the same

2.120 **(a)** $\vec{\omega}_1 = \left(104.7\,\hat{k}\right)\text{rad/s}$, $\vec{\omega}_2 = \left(104.7\,\hat{\imath}\right)\text{rad/s}$ and $\vec{\omega}_3 = \left(-104.7\,\hat{\jmath}\right)\text{rad/s}$

(b) $\vec{\omega}_\ell = \dfrac{100\pi}{3\sqrt{3}}\left(\hat{\imath} + \hat{\jmath} + \hat{k}\right)\text{rad/s} = 60.46\left(\hat{\imath} + \hat{\jmath} + \hat{k}\right)\text{rad/s}$

2.122 Derivation, so no answer needed.

2.124 $\vec{v}_A = 10.00\,\hat{\jmath}\,\text{m/s}$, $\vec{v}_B = 10.00\,\hat{\jmath}\,\text{m/s}$, $\vec{v}_C = 10.00\,\hat{\jmath}\,\text{m/s}$, and $\vec{v}_D = 10.00\,\hat{\jmath}\,\text{m/s}$

2.126 $\vec{\omega}_{\text{wheel}} = -65.71\,\hat{k}\,\text{rad/s}$

2.128 $|\vec{a}_P| = 19{,}300\,\text{ft/s}^2$

Orientation of $\vec{a}_P$ from x axis $= 110.0^\circ$ (ccw)

2.130 $v_0 = 263.7\,\text{ft/s}$ and $r = 6875\,\text{ft}$

2.132 $\dot{r} = -1.204\,\text{m/s}$ and $\dot{\theta} = -0.8504\,\text{rad/s}$

2.134 $\vec{v} = (0.037\,70\,\hat{u}_r + 0.5341\,\hat{u}_\theta)\,\text{m/s}$

$\vec{a} = \left(-1678\,\hat{u}_r + 236.9\,\hat{u}_\theta\right)\text{m/s}^2$

2.136 Concept Problem

2.138 $\dot{r}\big|_{\theta=90^\circ} = 8.825\,\text{ft/s}$ and $\dot{\phi}\big|_{\theta=90^\circ} = -0.7746\,\text{rad/s}$

2.140 $\vec{a}_P = (-252.9\,\hat{u}_C - 399.8\,\hat{u}_B)\,\text{ft/s}^2$

2.142 Concept Problem

2.144 Concept Problem

2.146 $\rho = 49.69\,\text{ft}$

2.148 $\dot{v} = 3.213\,\text{m/s}^2$

2.150 $\rho_{\text{Südkurve}} = 50.56\,\text{m}$

$\rho_{\text{Nordkurve}} = 92.54\,\text{m}$

2.152 $\rho = 327.3\,\text{ft}$

2.154 $d = 831.0\,\text{ft}$

2.156 $\vec{a} = \vec{0}$

2.158 $\vec{a} = (-39.40\,\hat{\imath} + 42.88\,\hat{\jmath})\,\text{m/s}^2$

2.160 Concept Problem

2.162 $|\vec{a}| = (33.69\times10^{-3}\cos\phi)\,\text{m/s}^2$

2.164 $\vec{a} = (121.2\,\hat{\imath} + 230.0\,\hat{\jmath})\,\text{ft/s}^2$

2.166 $\vec{a} = -\left(18.96\,\text{ft/s}^2\right)\hat{u}_t + \left[\left(69.91\,\text{ft/s}^2\right) - \left(0.2917\,\text{s}^{-2}\right)s\right]\hat{u}_n$

2.168 $\dot{v} = -5.343\,\text{m/s}^2$ and $\rho = 17.50\,\text{m}$

2.170 $\rho = 282.2\,\text{ft}$

2.172 $\rho_{\text{min}} = 564.5\,\text{ft}$

$t_f - t_0 = 4.742\,\text{s}$

2.174 $|\vec{a}| = \dfrac{1}{\rho}\left(v_0 - \dfrac{2v_0}{\pi\rho}s\right)\sqrt{\dfrac{4v_0^2}{\pi^2} + \left(v_0 - \dfrac{2v_0}{\pi\rho}s\right)^2}$

2.176 $d = 304.4\,\text{ft}$ and $t_f = 3.106\,\text{s}$

2.178 Concept Problem

2.180 Concept Problem

2.182 $\dot{r} = 684.1\,\text{ft/s}$ and $\dot{\theta} = -0.011\,57\,\text{rad/s}$

$\ddot{r} = 4.944\,\text{ft/s}^2$ and $\ddot{\theta} = 0.000\,428\,1\,\text{rad/s}^2$

2.184 $v = 1.816\,\text{m/s}$

$|\vec{a}| = 4.573\,\text{m/s}^2$

2.186 $\ddot{r} = 1.599\,\mathrm{m/s^2}$

2.188 $\theta_0 = 0$

$r_0 = 0.014\,86\,\mathrm{m}$

2.190 $\vec{v} = (-1.3\,\mathrm{m/s})\,\hat{u}_r + \left(0.22\,\mathrm{s^{-1}}\right) r\,\hat{u}_\theta$

$\vec{a} = -\left(0.048\,40\,\mathrm{s^{-2}}\right) r\,\hat{u}_r - \left(0.5720\,\mathrm{m/s^2}\right)\hat{u}_\theta$

2.192 $\vec{v} = (0.1500\,\hat{u}_r + 1.732\,\hat{u}_\theta)\,\mathrm{ft/s}$ and $\vec{a} = (-0.3638\,\hat{u}_r + 0.1125\,\hat{u}_\theta)\,\mathrm{ft/s^2}$

2.194 $\vec{r} = 30.20\,\hat{u}_r\,\mathrm{ft}$

$\vec{v} = (3\,\hat{u}_r + 7.550\,\hat{u}_\theta)\,\mathrm{ft/s}$

$\vec{a} = (-1.888\,\hat{u}_r + 1.500\,\hat{u}_\theta)\,\mathrm{ft/s^2}$

2.196 $\eta = 5.602\,\mu\mathrm{m}$

$\omega = 2630\,\mathrm{rad/s} = 25{,}120\,\mathrm{rpm}$

2.198 $v = 5490\,\mathrm{ft/s}$

$|\vec{a}| = 1.005\times 10^6\,\mathrm{ft/s^2}$

2.200 $\vec{v} = \dfrac{\kappa v_0}{\sqrt{\kappa^2 + (r_0 + \kappa\theta)^2}}\,\hat{u}_r + \dfrac{v_0(r_0 + \kappa\theta)}{\sqrt{\kappa^2 + (r_0 + \kappa\theta)^2}}\,\hat{u}_\theta$

$$\vec{a} = -\frac{v_0^2 (r_0 + \kappa\theta)^3}{\left[r_0^2 + 2r_0\kappa\theta + (1+\theta^2)\kappa^2\right]^2}\,\hat{u}_r + \frac{\kappa v_0^2 \left\{(r_0 + \kappa\theta)^2 + 2\left[\kappa^2 + (r_0 + \kappa\theta)^2\right]\right\}}{\left[\kappa^2 + (r_0 + \kappa\theta)^2\right]^2}\,\hat{u}_\theta$$

2.202 $\dot{\theta}_A = -0.001\,157\,\mathrm{rad/s}$ and $\dot{\theta}_H = -4.287\,\mathrm{rad/s}$

$\ddot{\theta}_A = -1.684\times 10^{-4}\,\mathrm{rad/s^2}$ and $\ddot{\theta}_H = -0.075\,47\,\mathrm{rad/s^2}$

2.204 $\dot{\vec{a}} = \left(\dddot{r} - 3r\dot{\theta}\ddot{\theta} - 3\dot{r}\dot{\theta}^2\right)\hat{u}_r + \left[r\left(\dddot{\theta} - \dot{\theta}^3\right) + 3\ddot{r}\dot{\theta} + 3\dot{r}\ddot{\theta}\right]\hat{u}_\theta$

2.206 $\ddot{r} = 5.781\,\mathrm{ft/s^2}$

$\ddot{\theta} = -1.421\,\mathrm{rad/s^2}$

2.208 $r = \sqrt{h^2 + (d+\rho)^2}$

$\dot{r} = \dfrac{v_0 h}{\sqrt{h^2 + (d+\rho)^2}}$ and $\dot{\theta} = \dfrac{v_0(d+\rho)}{h^2 + (d+\rho)^2}$

$\ddot{r} = -\dfrac{v_0^2}{\rho}\dfrac{(\rho + d)\left(d^2 + h^2 + d\rho\right)}{\left(d^2 + h^2 + \rho^2 + 2d\rho\right)^{3/2}}$ and $\ddot{\theta} = \dfrac{v_0^2}{\rho}\dfrac{h\left(d^2 + h^2 - \rho^2\right)}{\left(d^2 + h^2 + \rho^2 + 2d\rho\right)^2}$

2.210 $\vec{v} = 1.758\,\hat{\jmath}\,\mathrm{m/s}$ and $\vec{a} = 136.9g\,\hat{\jmath}$

2.212 $v = 0.1185\,\mathrm{ft/s}$ and $|\vec{a}| = 0.086\,42\,\mathrm{ft/s^2}$

2.214 $a_r = \dfrac{K^2 a}{b^2}\left(-\dfrac{1}{r^2}\right)$

2.216 Computer Problem

2.218 Concept Problem

2.220 $v_{H/F} = \left[5.630\times10^{-5} - 0.8091\cos\left(\dfrac{\pi x}{2}\right)\right]$ m/s

$a_{H/F} = 5.237\sin\left(\dfrac{\pi x}{2}\right)$ m/s^2

2.222 $v_{A/B} = 144.7$ m/s

2.224 $\vec{v}_{C/A} = (6.857\,\hat{\imath} + 30.27\,\hat{\jmath})$ m/s.

$\vec{a}_{C/A} = (1.376\,\hat{\imath} - 1.000\,\hat{\jmath})$ m/s^2.

2.226 $(v_P)_{\text{avg}} = 17.30$ ft/s

2.228 Computer Problem

2.230 $v_{p_{\max}} = 330.7$ ft/s $= 225.4$ mph

2.232 $\vec{v}_B = 2.928\,\hat{\imath}$ ft/s

2.234 $v_{\text{rain}} = 16.37$ ft/s

2.236 $$\vec{a}_B = \left(L_1\ddot{\theta}\cos\theta - L_1\dot{\theta}^2\sin\theta + L_2\ddot{\phi}\cos\phi - L_2\dot{\phi}^2\sin\phi\right)\hat{\imath} + \left(L_1\ddot{\theta}\sin\theta + L_1\dot{\theta}^2\cos\theta + L_2\ddot{\phi}\sin\phi + L_2\dot{\phi}^2\cos\phi\right)\hat{\jmath}$$

2.238 $\theta = 63.57°$

2.240 $\theta = 14.90°$

2.242 $\vec{v}_B = -3.088\,\hat{\jmath}$ ft/s.

$\vec{a}_B = -0.3192\,\hat{\jmath}$ ft/s^2.

2.244 $\vec{v}_B = -2.000\,\hat{\jmath}$ m/s.

2.246 $v_{Ay} = -4.596$ ft/s.

2.248 $\vec{a}_B = -11.10\,\hat{\imath}$ m/s^2. @θ

$t_d = 0.1644$ s

2.250 $a_0 = 0.9374$ ft/s^2

2.252 $\dot{\ell} = \dfrac{d v_0}{\sqrt{h^2 + d^2}}$

2.254 Component of $\vec{v}_{C/B}$ along $\overline{BC} = 0$

2.256 $r = \sqrt{(d + \rho\cos\phi)^2 + (h + \rho\sin\phi)^2}$

$$\dot{\theta} = \frac{v_0(\rho + d\cos\phi + h\sin\phi)}{(d + \rho\cos\phi)^2 + (h + \rho\sin\phi)^2} \quad \text{and} \quad \dot{r} = \frac{v_0(h\cos\phi - d\sin\phi)}{\sqrt{(d + \rho\cos\phi)^2 + (h + \rho\sin\phi)^2}}$$

2.258 $t = 0.1556\,\text{s}$

2.260 $\ddot{y}_e = -9.81\,\text{m/s}^2$

$\ddot{y}_C\big|_{t=0.4391\,\text{s}} = -44.51\,\text{m/s}^2$

2.262 Concept Problem

2.264 Concept Problem

2.266 $\Delta t = 83.82\,\text{s}$

2.268 $\vec{v}_C = (-6.500\,\hat{u}_R + 5.520\,\hat{u}_\theta + 5.300\,\hat{u}_z)\,\text{ft/s}$

$\vec{a}_C = (-0.6624\,\hat{u}_R - 1.560\,\hat{u}_\theta)\,\text{ft/s}^2$

2.270

$$r\dot{\phi}(r\ddot{\theta}\sin\phi + 2\dot{r}\dot{\theta}\sin\phi + 2r\dot{\phi}\dot{\theta}\cos\phi) - r\dot{\theta}\sin\phi(r\ddot{\phi} + 2\dot{r}\dot{\phi} - r\dot{\theta}^2\sin\phi\cos\phi) = 0,$$
$$r\dot{\theta}\sin\phi(\ddot{r} - r\dot{\phi}^2 - r\dot{\theta}^2\sin^2\phi) - \dot{r}(r\ddot{\theta}\sin\phi + 2\dot{r}\dot{\theta}\sin\phi + 2r\dot{\phi}\dot{\theta}\cos\phi) = 0,$$
$$\dot{r}(r\ddot{\phi} + 2\dot{r}\dot{\phi} - r\dot{\theta}^2\sin\phi\cos\phi) - r\dot{\phi}(\ddot{r} - r\dot{\phi}^2 - r\dot{\theta}^2\sin^2\phi) = 0$$

2.272 $\vec{v} = (0.04869\,\hat{u}_R + 7.961\,\hat{u}_\theta - 0.2999\,\hat{u}_z)\,\text{m/s}$

$\vec{a} = (-79.79\,\hat{u}_R + 0.9738\,\hat{u}_\theta - 0.8120\,\hat{u}_z)\,\text{m/s}^2$

2.274 $\left|\vec{a}_{\phi_{\max}}\right| = 12.36\,\text{ft/s}^2$

2.276 $\vec{v} = \dfrac{df}{dz}\dot{z}\,\hat{u}_r + \dfrac{K}{f(z)}\,\hat{u}_\theta + \dot{z}\,\hat{u}_z$

$$\vec{a} = \left(\ddot{z} + \dot{z}^2\frac{d^2 f}{dz^2} - \frac{K^2}{f^3(z)}\right)\hat{u}_R + \ddot{z}\,\hat{u}_z$$

2.278 $a_r = -0.1598\,\text{m/s}^2$, $a_\phi = -0.1884\,\text{m/s}^2$, and $a_\theta = 0.2232\,\text{m/s}^2$

2.280 $\vec{v}_{P/B} = (10.17\,\hat{\imath}_B + 10.33\,\hat{\jmath}_B)\,\text{m/s}$ and $v_{P/B} = v_{P/A} = 14.50\,\text{m/s}$

$\vec{a}_{P/B} = (7.822\,\hat{\imath}_B - 1.258\,\hat{\jmath}_B)\,\text{m/s}^2$ and $\left|\vec{a}_{P/B}\right| = \left|\vec{a}_{P/A}\right| = 7.923\,\text{m/s}^2$

2.282 Concept Problem

2.284 Computer Problem

2.286 $s = \dfrac{mg}{C_d^2}\left[C_d t + m\left(e^{-\frac{C_d}{m}t} - 1\right)\right]$

2.288 $x = \left(L_0 + \dfrac{gm}{k}\right)\left[1 - \cos\left(\sqrt{\dfrac{k}{m}}\,t\right)\right]$

2.290 $v_0 \geq \sqrt{gR}$

2.292 $\rho = 240.5\,\text{ft}$

2.294 The car will lose contact with the ground.

$a_c = -1.606\,\text{m/s}^2$

2.296 $\dot{r}\big|_{\theta=180^\circ} = 0$

$\dot{\phi}\big|_{\theta=180^\circ} = -2.941\,\text{rad/s}$

$\ddot{r}\big|_{\theta=180^\circ} = -40.85\,\text{m/s}^2$ and $\ddot{\phi}\big|_{\theta=180^\circ} = 0$

2.298 $\dot{\theta} = 0.053\,91\,\text{rad/s}$

$\ddot{\theta} = -0.2380\,\text{rad/s}^2$

2.300 $v_{\text{max}} = 6.020\,\text{ft/s}$

2.302 $h_{\text{max}} = 0.8898\,\text{ft}$

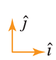
2.304 $|\vec{a}_A| = 18.65\,\text{m/s}^2$

2.306 $|\vec{a}| = 172{,}700\,\text{ft/s}^2$

2.308 $|\vec{a}|_{\phi_{\text{min}}} = 2.534\,\text{m/s}^2$

Chapter 3

3.2 Concept Problem

3.4 $\vec{a}_A = 2.147\,\hat{\jmath}\,\text{ft/s}^2$.


3.6 $a_{\text{max}} = 17.75\,\text{ft/s}^2$

3.8 $a_{B_{\text{max}}} = 0.1650\,\text{m/s}^2 = 0.5417\,\text{ft/s}^2$

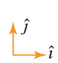
3.10 $\ddot{x} + \dfrac{EA}{mL}x = 0$

3.12 $a_{B_{\text{max}}} = 5.048\,\text{m/s}^2 = 16.57\,\text{ft/s}^2$

3.14 $d = 6.630\,\text{ft}$

3.16 $d = 417.5\,\text{ft}$

If an entire train weighing 30×10^6 lb was skidding to a stop, instead of a locomotive, we would have the same stopping distance because the weight does not appear in our solution.

3.18 $\vec{a} = \left(\dfrac{C_d}{m}v^2 - g\right)\hat{\jmath}$.


3.20 $(\mu_s)_{\text{min}} = 0.3436$

3.22 $v_i = 5.297\,\text{ft/s}$

3.24 Computer Problem

3.26 $v_i = 32.68 \times 10^{-6}$ m/s

3.28 $v_{\text{max}} = g\sqrt{\dfrac{m}{k}}$

3.30 Spring compression = 0.7367 ft

3.32 $k = 5.084 \times 10^4$ lb/ft

3.34 $\delta_{\text{max}} = 0.1675$ m

$(F_s)_{\text{max}} = 586.1$ N

3.36 Computer Problem

3.38 $x_{\text{stop}} = 0.1597$ m

3.40 $k = 5.930$ lb/ft

3.42 $k = 9034$ kg/s^2

3.44 $v(0) = \sqrt{2\dfrac{k}{m}\left[x_0^2 + 2L_0\left(L - \sqrt{x_0^2 + L^2}\right)\right]}$

3.46 Concept Problem

3.48 Concept Problem

3.50 Concept Problem

3.52 $\rho = 1.401 \times 10^4$ ft

3.54 No value of ω_c can be found that would cause the person to slide up the wall

3.56 $(F_{OA})_{\text{before release}} = \dfrac{mg}{\cos\theta}$, $(F_{OA})_{\text{after release}} = mg\cos\theta$, (% change in $F_{OA})_{\theta=30°} = -25.00\%$

3.58 $|\vec{a}| = 3.620\, g$

$|F_L| = 43{,}060$ N

3.60 $\ddot{x} + \dfrac{k}{m}x\left(1 - \dfrac{r_u}{\sqrt{x^2+y^2}}\right) = 0,$

$\ddot{y} + \dfrac{k}{m}y\left(1 - \dfrac{r_u}{\sqrt{x^2+y^2}}\right) = 0$

3.62 $\ddot{r} - r\dot{\theta}^2 + \dfrac{k}{m}(r - r_u) - g\cos\theta = 0$ and $r\ddot{\theta} + 2\dot{r}\dot{\theta} + g\sin\theta = 0$

3.64 $t_s = 0.7466$ s

3.66 $y = \dfrac{m}{C_d}\tan\theta_0\left(e^{C_d x/m} - 1\right) - \dfrac{m^2 g}{2C_d^2 v_0^2\cos^2\theta_0}\left(e^{C_d x/m} - 1\right)^2$

3.68
$$a_\phi = 0 = a_z,$$
$$a_R = -\frac{g(\mu_s + \tan\theta)}{1 - \mu_s \tan\theta} = -120.1\,\text{ft/s}^2,$$
$$F_\phi = 0,$$
$$F = \frac{\mu_s mg}{\cos\theta - \mu_s \sin\theta} = (83.16\,\text{ft/s}^2)\,m,$$
$$N = \frac{mg}{\cos\theta - \mu_s \sin\theta} = (92.40\,\text{ft/s}^2)\,m,$$
$$v_{\max} = \sqrt{\rho g}\sqrt{\frac{\mu_s + \tan\theta}{1 - \mu_s \tan\theta}} = 363.4\,\text{ft/s} = 247.8\,\text{mph}$$

3.70 $F = 5971\,\text{lb}$

3.72 $(\omega_c)_{\max} = 2.733\,\text{rad/s}$

3.74 **(a)** $\vec{a} = (318.8\times 10^3\,\hat{u}_r + 603.0\,\hat{u}_\theta)\,\text{m/s}^2$
(b) $P = 5.898\times 10^6\,\text{N}$ and $R = 11.33\times 10^3\,\text{N}$

3.76 $\omega = 9.939\,\text{rad/s}$

3.78 $\theta_B = 41.81°$

3.80 Concept Problem

3.82 $\ddot{r} - r\dot{\theta}^2 + G\dfrac{m_e}{r^2} = 0$ and $r\ddot{\theta} + 2\dot{r}\dot{\theta} = 0$

3.84
$$\delta_{\min} = \sqrt{\frac{5mgr}{k}}$$
$$v_B = \sqrt{2gr}$$

3.86 Computer Problem

3.88 $h_{\max} = 0.3618\,\text{ft}$

3.90
$$\ddot{x}\big(L^2 - y^2\big) + \ddot{y}xy + x\frac{\dot{x}^2\big(L^2 - y^2\big) + \dot{y}^2\big(L^2 - x^2\big) + 2xy\dot{x}\dot{y}}{L^2 - x^2 - y^2} + gx\sqrt{L^2 - x^2 - y^2} = 0,$$
$$\ddot{y}\big(L^2 - x^2\big) + \ddot{x}xy + y\frac{\dot{x}^2\big(L^2 - y^2\big) + \dot{y}^2\big(L^2 - x^2\big) + 2xy\dot{x}\dot{y}}{L^2 - x^2 - y^2} + gy\sqrt{L^2 - x^2 - y^2} = 0$$

3.92 $\ddot{\phi} - \dot{\theta}^2 \sin\phi\cos\phi + (g/L)\sin\phi = 0$ and $\ddot{\theta}\sin\phi + 2\dot{\phi}\dot{\theta}\cos\phi = 0$

3.94 $\ddot{r} - r\dot{\theta}^2 = 0$ and $r\ddot{\theta} + 2\dot{r}\dot{\theta} = 0$

3.96
$$M_z = 2m\omega_0^2 r\sqrt{r^2 - r_0^2}$$
$$|v_r| = \omega_0\sqrt{d^2 + 2dr_0}$$
$$v = \omega_0\sqrt{2d^2 + 4dr_0 + r_0^2}$$

3.98 Concept Problem

3.100 $\theta = \tan^{-1}\mu_s - \sin^{-1}\left(\dfrac{\mu_s v_0^2}{\rho g\sqrt{1+\mu_s^2}}\right)$

$\theta = 15.59°$

3.102 Concept Problem

3.104 $\ddot{\vec{r}}_{B/A} = -G\left(\dfrac{m_A + m_B}{r^2}\right)$

3.106 $\vec{a}_A = 16.10\,\hat{\jmath}\ \text{ft/s}^2$

3.108 $\vec{a}_A = \dfrac{m_A + m_B - 4m_P}{m_A + m_B} g\,\hat{\jmath}.$

3.110 $\vec{a} = -4.414\,\hat{\imath}\ \text{m/s}^2.$

3.112 $N_{AB} = 675.7\,\text{N}$ and $|\vec{a}_A| = |\vec{a}_B| = 3.355\,\text{m/s}^2$

3.114 $\vec{a} = 226.1\,\hat{\imath}\ \text{ft/s}^2$ and $\vec{a}_B = \vec{0}.$

3.116 $|\vec{a}_A| = 4.075\,\text{m/s}^2$ up the incline, $|\vec{a}_B| = 2.037\,\text{m/s}^2$ downward, $T = 38.86\,\text{N}$

3.118 $\vec{a}_A = 4.204\,\hat{\imath}\ \text{m/s}^2$, $\vec{a}_B = -5.606\,\hat{\jmath}\ \text{m/s}^2$, and $|F_b| = 21.02\,\text{N}$ in compression

3.120 $W_{\text{max}} = 2mg$

3.122 $v_{\text{impact}} = 3.691\,\text{m/s}$

3.124 $d \geq \dfrac{2\mu_k(m_A + m_B)g}{k}$

3.126 $N_B = 5922\sin\theta\ \text{N}$

$(N_B)_{\text{max}} = \frac{1}{2}m_A d\omega^2 = 5922\,\text{N}$

3.128 $\ddot{\theta} = -\dfrac{g}{2R}\left[\left(2 - \dfrac{d^2}{2R^2}\right)\sin\theta - \dfrac{d}{R^2}\sqrt{R^2 - \tfrac{1}{4}d^2}\cos\theta\right]$

3.130 $T = 239.6\,\text{N}$

3.132 $d_{B_{\text{max}}} = 2\,\text{ft}$

$v_{B_{\text{max}}} = 8.579\,\text{ft/s}$

3.134 $d_{B_{\text{max}}} = 1.840\,\text{ft}$

$v_{B_{\text{max}}} = 4.787\,\text{ft/s}$

3.136 $(m_A + m_B)\ddot{x}_B + m_A L\ddot{\theta}\cos\theta - m_A L\dot{\theta}^2\sin\theta = 0,$

$m_B\ddot{x}_B\cot\theta - m_A L\ddot{\theta}\sin\theta - m_A L\dot{\theta}^2\cos\theta = m_A g$

3.138 $P = 748.4\,\text{N}$

3.140 $d = 3.162\times10^{-3}\,\text{ft}$

3.142 $t_{\text{contact}} = 96{,}140\,\text{s} = 26.71\,\text{h}$

3.144 Number of rotations $= 0.7776$

3.146 $F_{\text{restraint}} = 1158\,\text{N}$

3.148 $v_0 = 4.428\,\text{ft/s}$

3.150 $y = \left(\tan\beta + \dfrac{mg}{v_0\eta\cos\beta}\right)x + \dfrac{m^2 g}{\eta^2}\ln\left(1 - \dfrac{\eta x}{m v_0 \cos\beta}\right)$

3.152 $\vec{a}_A = -0.2688\,\hat{\jmath}\ \text{m/s}^2$ and $T = 1209\,\text{N}$.

3.154 $t_{\text{ss}} = \dfrac{v_0}{\mu_k g}$ and $d_{\text{ss}} = \dfrac{v_0^2}{2\mu_k g}$

3.156 $\vec{a}_A = (2.685\,\hat{\imath} - 2.139\,\hat{\jmath})\,\text{m/s}^2$.

3.158 Computer Problem

Chapter 4

4.2 Concept Problem

4.4 $(U_{1\text{-}2})_N = 1810\,\text{J}$ and $(U_{1\text{-}2})_{F_g} = -1570\,\text{J}$,

$|(U_{1\text{-}2})_N| \neq |(U_{1\text{-}2})_{F_g}|$ because $N \neq mg$ due to the fact that the man is accelerating.

4.6 $U_{1\text{-}2} = 360.7\times10^3\,\text{ft·lb}$

4.8 $v_2 = d\sqrt{k/m}$

4.10 $U_{1\text{-}2} = 117.2\,\text{kJ}$

4.12 $U_{1\text{-}2} = 288.5\,\text{ft·lb}$

4.14 $(U_{1\text{-}2})_{\text{friction}} = 1870\,\text{J}$

4.16 $d = 25.22\,\text{m}$

4.18 Concept Problem

4.20 $v_2 = 35.62\,\text{ft/s}$

4.22 Computer Problem

4.24 Energy lost to permanent deformation $= 4.984\times10^{-11}\,\text{J}$

4.26 $v_1 = 7.093\,\text{ft/s}$

4.28 Computer Problem

4.30 $\beta = 1.293\times10^{-5}\,\text{lb/ft}^3$

4.32 $k = 273.9\times10^3\,\mathrm{N/m}$

4.34 $v_0 = 6.400\,\mathrm{ft/s}$

4.36 $k = 44.81\,\mathrm{lb/ft}$

4.38 $(U_{1\text{-}2})_{\text{engine}} = 464.4\times10^3\,\mathrm{ft{\cdot}lb}$

4.40 $(F_p)_{\text{avg}} = 1471\,\mathrm{N}$

4.42 $R = 4425\,\mathrm{ft}$

4.44 $v_2 = 6.348\,\mathrm{m/s}$

4.46 $v_2 = 18.52\,\mathrm{m/s}$

4.48 $k = 4316\,\mathrm{N/m}$

4.50 $V = k\dfrac{q_A q_B}{r}$

4.52 $v_A = 2336\,\mathrm{m/s}$

4.54 $\theta_{(v_B)_{\text{max}}} = 0$

$(v_B)_{\text{max}} = 0.3822\,\mathrm{m/s}$

4.56 $\delta_{\text{min}} = \sqrt{\dfrac{5mgr}{k}}$ and $v_B = \sqrt{2gr}$

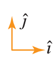
4.58 **(a)** $v_2 = 1626\,\mathrm{ft/s}$

(b) $v_2 = 1522\,\mathrm{ft/s}$

(c) The form of the potential energy allows us to interpret the work done by the expanding gas as the work of the force $P_0 A$ along an effective distance $s_0 \log s_2/s_0$. The force $P_0 A$ is the same in both cases. However, the decrease in s_0 in Part (b) is such that the effective distance over which the force acts is smaller, thus causing v_2 to be smaller in Part (b).

4.60 $h_{\text{max}} = 0.1055\,\mathrm{m}$

4.62 **(a)** $V_c = \frac{1}{2}k\delta^2 - \frac{1}{4}\beta\delta^4$

$\vec{v}_{\text{bottom}} = -5.161\,\hat{\jmath}\,\mathrm{ft/s}.$ 

(b) $|\vec{a}|_{\text{max}} = 1.599g$

4.64 $\mu_k = 0.8343$

4.66 $V = 4\epsilon\left[\left(\dfrac{\sigma}{r_{ij}}\right)^{12} - \left(\dfrac{\sigma}{r_{ij}}\right)^{6}\right]$

4.68 $v_{\text{max}} = g\sqrt{\dfrac{m}{k}}$

4.70 $L_0 = 1.060\,\mathrm{m}$

4.72 $v_{A2} = 1.093\,\mathrm{m/s}$ and $v_{B2} = 3.278\,\mathrm{m/s}$

4.74 $d_{B_{\text{max}}} = 2.500\,\mathrm{ft}$

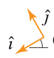
4.76 $v_{B2} = 5.648\,\mathrm{m/s}$

4.78 $v_{B2} = 33.23\,\mathrm{ft/s}$

4.80 $v_{A2} = 13.77\,\mathrm{ft/s}$

4.82 $W = 2mg$

4.84 The work done by the tension in the cord on A is equal and opposite to the corresponding work done by the tension in the cord on B. Thus the net work done by the tension in the cord on the system is equal to zero.

$\vec{v}_{A2} = 0.1424\,\hat{\imath}\,\mathrm{m/s}$ and $\vec{v}_{B2} = -0.4273\,\hat{\imath}\,\mathrm{m/s}$ 

@θ

4.86 $v_2 = \sqrt{Pl(1 - \sin\theta_0)/m}$

4.88 distance of B from the floor $= 0$ and $v_{\max} = 9.422\,\mathrm{ft/s}$

4.90 $h_{\max} = 21.85\,\mathrm{ft}$

4.92 $v_{A2} = 7.001\,\mathrm{m/s}$ and $v_{B2} = 14.00\,\mathrm{m/s}$

4.94 $v = s\sqrt{\dfrac{g}{l}}$

4.96 Computer Problem

4.98 $P_{\mathrm{avg}} = 375.0\,\mathrm{ft{\cdot}lb/s} = 0.6818\,\mathrm{hp}$

4.100 Concept Problem

4.102 $\theta = 6.321^\circ$

4.104 $v_2 = 13.62\,\mathrm{mph}$

4.106 $P = 162.4\,\mathrm{hp}$

4.108 $v_B = 2.128\,\mathrm{m/s}$

4.110 $P_i = 1.247\,\mathrm{hp}$

4.112 $v = 9.895\,\mathrm{ft/s}$

4.114 $v_{B2} = 10.84\,\mathrm{m/s}$

4.116 $v_{A2} = 3.631\,\mathrm{m/s}$

4.118 Concept Problem

4.120 $(U_{1\text{-}2})_d = -0.1585\,\mathrm{ft{\cdot}lb}$

4.122 $k = 9034\,\mathrm{N/m}$

4.124 $v_2 = 73.55\,\mathrm{ft/s}$

4.126 $v_{\max} = 9.674\,\mathrm{ft/s}$ and is achieved when the distance of B from the ground is zero.

4.128 $E_b = 1290\,\mathrm{C}$

4.130 $P = \begin{cases} 4637\,\mathrm{ft{\cdot}lb/s}, & \text{for case (a)}, \\ 343.5\,\mathrm{ft{\cdot}lb/s}, & \text{for case (b)}. \end{cases}$

Chapter 5

5.2 Concept Problem

5.4 Concept Problem

5.6 Concept Problem

5.8 $d = 28.46\times 10^{-24}\,\mathrm{m}$

$d = 4.152\times 10^{-15}\,\mathrm{m}$

$d = 1.423\times 10^{-6}\,\mathrm{m}$

5.10 $\displaystyle\int_{t_1}^{t_2} \vec{F}\,dt = -93.17\,\hat{\jmath}\,\mathrm{lb{\cdot}s}$

5.12 $\displaystyle\left|\int_{t_1}^{t_2} \vec{F}\,dt\right| = 2.635\,\mathrm{lb{\cdot}s}$

$\left|\vec{F}_{\mathrm{avg}}\right| = 2396\,\mathrm{lb}$

5.14 $F_{\mathrm{avg}} = 2589\,\mathrm{lb}$

5.16 $v\big|_{t=2\,\mathrm{s}} = 4.293\,\mathrm{ft/s}$

5.18 $\tau = 1.610\,\mathrm{s}$

5.20 $\left|\vec{F}_b\right|_{\mathrm{avg}} = 40{,}640\,\mathrm{lb}$

5.22 $v\big|_{t=2.5\,\mathrm{s}} = 9.045\,\mathrm{m/s}$

5.24 Impulse imparted to the ball by kicker $= 2.531\,\hat{\jmath}\,\mathrm{lb{\cdot}s}$

$\left(\vec{F}_k\right)_{\mathrm{avg}} = 316.4\,\hat{\jmath}\,\mathrm{lb}$

5.26 $t_2 = 10.57\,\mathrm{s}$

$d = 1279\,\mathrm{ft}$

5.28 $\left(\vec{F}_c\right)_{\mathrm{avg}} = (219.3\,\hat{\imath} + 192.4\,\hat{\jmath})\,\mathrm{N}$

5.30 **(a)** $\left|\vec{F}_{\mathrm{avg}}\right| = 8081\,\mathrm{N}$
(b) $\mu_s = 0.5148$

5.32 Impulse provided by floor $= (14.93\,\mathrm{N{\cdot}s})\,\hat{\jmath}$.

$\vec{a}_{\mathrm{avg}} = \left(5420\,\mathrm{m/s^2}\right)\hat{\jmath} = 552.5g\,\hat{\jmath}$.

5.34 Impulse of the rope $= 16.30\,\hat{\imath}\,\mathrm{lb{\cdot}s}$

5.36 $\vec{v}_B = 5.094\times 10^6\,\hat{\imath}\,\mathrm{ft/s}$.

5.38 number of worker bees $= 9.062\times 10^6$

slowdown $= 48.11\,\mathrm{ft/s} = 32.80\,\mathrm{mph}$

5.40 $\vec{v}_A = 8.455\,\hat{\imath}\,\mathrm{m/s}$ and $\vec{v}_B = 7.455\,\hat{\imath}\,\mathrm{m/s}$

5.42 $\vec{v}_A\big|_{t=1.5\,\mathrm{s}} = 0.7905\,\hat{\imath}\,\mathrm{m/s}$ and $\vec{v}_B\big|_{t=1.5\,\mathrm{s}} = -2.371\,\hat{\imath}\,\mathrm{m/s}$

5.44 $v_{P2} = 1.714\,\mathrm{ft/s}$

5.46 $v_{P3} = 1.852\,\mathrm{ft/s}$

5.48 $d = 4.951\,\mathrm{m}$

5.50 $(\vec{v}_P)_{\mathrm{final}} = (1.516\,\mathrm{ft/s})\,\hat{\imath}$.

5.52 $d = 1.017\,\mathrm{ft}$

5.54 $\vec{v}_A = 11.17\,\hat{\imath}\,\mathrm{m/s}$ and $\vec{v}_B = -3.624\,\hat{\imath}\,\mathrm{m/s}$

5.56 **(a)** $\vec{v}_{A2} = (-8.826\,\hat{\imath} - 10.76\,\hat{\jmath})\,\mathrm{ft/s}$ and $\vec{v}_{B2} = 13.24\,\hat{\imath}\,\mathrm{ft/s}$.

5.58 $\vec{v}_{A2} = (-10.29\,\mathrm{ft/s})\,\hat{\imath}$ and $\vec{v}_{B2} = (51.46\,\mathrm{ft/s})\,\hat{\imath}$.

5.60

$$\vec{v}_B = \pm\frac{m_A\cos\theta\sqrt{2gL}\sqrt{\cos\theta-\cos\theta_0}}{\sqrt{(m_A-m_B)^2 - m_A(m_A-3m_B)\cos^2\theta}}\,\hat{\imath},$$

$$v_A = \sqrt{2gL}\sqrt{\cos\theta-\cos\theta_0}\sqrt{\frac{(m_A-m_B)^2 - m_A(m_A-2m_B)\cos^2\theta}{(m_A-m_B)^2 - m_A(m_A-3m_B)\cos^2\theta}}$$

5.62 **(a)** $v_{AR} = 0.3750\,\mathrm{ft/s}$

(b) $\vec{F}_A = -[(447.2\,\mathrm{lb}) + (10.48\,\mathrm{lb/s})t]\,\hat{u}_{R_A} + (139.8\,\mathrm{lb})\,\hat{u}_{\theta_A}$,

$\vec{F}_B = -[(174.7\,\mathrm{lb}) + (10.48\,\mathrm{lb/s})t]\,\hat{u}_{R_B} + (139.8\,\mathrm{lb})\,\hat{u}_{\theta_B}$

(c) $\vec{v}_G = (1.170\,\mathrm{ft/s})\,\hat{u}_{\theta_G} + (1.400\,\mathrm{ft/s})\,\hat{k}$ $\vec{a}_G = (-0.$

5.64 Concept Problem

5.66 $\vec{v}_A^{\,+} = \vec{v}_B^{\,+} = (-38.09\,\mathrm{mph})\,\hat{\imath}$.

5.68 $\delta = 0.041\,75\,\mathrm{ft}$

5.70 $v_B^- = 209.7\,\mathrm{m/s}$

5.72 $v_A^+ = 2.346\,\text{ft/s}$ and $v_B^+ = 4.154\,\text{ft/s}$

5.74 $e = m_A/m_B$

5.76 $0.7280 \le e \le 0.7616$

5.78 $\Delta t_A = 0.5184\,\text{s}$ and $\Delta t_B = 0.6600\,\text{s}$

5.80 $d = 2.887\,\text{m}$

5.82 $W_{\text{max}} = 818.6\,\text{lb}$

5.84 $v_{Ax}^+ = 0,\quad v_{Bx}^+ = 0,\quad v_{Cx}^+ = 6\,\text{ft/s}$

5.86 Treat each impact as only involving two balls. Because the COR $e = 1$ and the masses are identical we see from the solution to Problem 5.74 that ball 1 will come to a complete stop after impacting with ball 2. We also see that ball 2 will have a post impact velocity identical to the pre impact velocity of ball 1. Each ball in the train is tangent to the next so it will not appear to move at all during its impact with the next ball. Ball 4 impacts ball 5 which is free to move. Ball 5 will have a post impact velocity equal to the pre impact velocity of ball 1. The work-energy principle tells us that ball 5 will stop moving when it has reached the initial height ball 1 was released from. Finally, since the lengths of the pendulums are identical the maximum swing angle of ball 5 is equal to the initial release angle of ball 1.

5.88 Balls 3, 4, and 5 will swing up as a single unit until reaching the height that balls 1, 2, and 3 were released from while balls 1 and 2 will hang motionless.

5.90 $\vec{v}_A^+ = 53.19\,\hat{\jmath}\,\text{mph} = 78.01\,\hat{\jmath}\,\text{ft/s}$ and $\vec{v}_B^+ = (50\,\hat{\imath} + 53.19\,\hat{\jmath})\,\text{mph} = (73.33\,\hat{\imath} + 78.01\,\hat{\jmath})\,\text{ft/s}$

$\vec{r}_A = 135.0\,\hat{\jmath}\,\text{ft}$ and $\vec{r}_B = (174.2\,\hat{\imath} + 185.3\,\hat{\jmath})\,\text{ft}$.

5.92 Given the assumption that the masses are not identical, it is not possible to have a moving ball A hit a stationary ball B so that A stops right after the impact.

5.94 $\vec{v}_B^+ = 0.7071\,\hat{\jmath}\,\text{m/s}$. @ $-45°$

5.96 $v_B^- = 0.6886\,\text{ft/s}$

5.98 $\beta = \tan^{-1}(\cot\alpha)$

5.100 $\vec{v}_A^+ = (-8.309\,\hat{\imath} + 18.53\,\hat{\jmath})\,\text{m/s}$ and $\vec{v}_B^+ = (-8.309\,\hat{\imath} - 6.202\,\hat{\jmath})\,\text{m/s}$.

5.102 $d = 5.266\,\text{ft}$

5.104 $v_B^+ = 3\sqrt{2gh}$

5.106 $h_i = e^{2i}h_0$

$$t_i = \left(1 - e^i\right)\frac{1+e}{1-e}\sqrt{\frac{2h_0}{g}}$$

$t_{\text{stop}} = 13.27\,\text{s}$

5.108 Concept Problem

5.110 $\vec{h}_O = 513.1\times10^3\,\hat{k}\,\text{slug}\cdot\text{ft}^2/\text{s}$.

5.112 $\vec{h}_O(t_1) = \left(-0.009705\,\hat{\imath} + 0.08734\,\hat{\jmath} - 0.05823\,\hat{k}\right)\,\text{slug}\cdot\text{ft}^2/\text{s}$

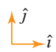
$\vec{h}_O(t_2) = \left(-0.01941\,\hat{\imath} - 0.01941\,\hat{\jmath} + 0.01941\,\hat{k}\right)\,\text{slug}\cdot\text{ft}^2/\text{s}$

5.114 Concept Problem

5.116 $(\vec{h}_B)_A = \left(120.0\,\hat{\imath} - 84.00\,\hat{\jmath} - 42.00\,\hat{k}\right)\,\text{kg}\cdot\text{m/s}$

5.118 The angular impulse provided to the pendulum bob between ① and ② is equal to zero.

5.120 $\vec{v}_{An} = (-13.33\,\hat{\imath} + 6.667\,\hat{\jmath})\,\text{m/s}$

5.122 $\vec{h}_O = -\left(142.8\times 10^3\,\text{kg}\cdot\text{m}^2/\text{s}^3\right)t^2\,\hat{k}$. 

5.124 Since $\dot{\vec{h}}_E + \vec{v}_E \times m_P \vec{v}_P = m_P g t[v_E - v_P(0)\cos\theta]\,\hat{k}$ and $\vec{M}_E = m_P g t[v_E - v_P(0)\cos\theta]\,\hat{k}$, it is true that $\vec{M}_E = \dot{\vec{h}}_E + \vec{v}_E \times m_P \vec{v}_P$.

5.126 $\ddot{\theta} = -\dfrac{g}{L}\sin\theta$

5.128 $v_{\text{impact}} = 0.4714\,\text{m/s}$

5.130 $\ddot{r} - r\dot{\theta}^2 = 0 \quad \text{and} \quad mr^2\ddot{\theta} + 2mr\dot{r}\dot{\theta} = M$

5.132 $k = 26.40\,\text{N/m}$

5.134 $v_2 = 18.39\,\text{m/s}$

5.136 $\text{Area}(P_1 O P_2)/\text{Area}(P_3 O P_4) = 1$

5.138 $e = \sqrt{1 + \dfrac{2E\kappa^2}{(Gm_B)^2}}$

(a) $E < 0 \quad\Rightarrow\quad 1 + \dfrac{2E\kappa^2}{(Gm_B)^2} < 1 \quad\Rightarrow\quad e < 1 \quad\Rightarrow$ elliptical orbit.

$E = 0 \quad\Rightarrow\quad 1 + \dfrac{2E\kappa^2}{(Gm_B)^2} = 1 \quad\Rightarrow\quad e = 1 \quad\Rightarrow$ parabolic trajectory.

$E > 0 \quad\Rightarrow\quad 1 + \dfrac{2E\kappa^2}{(Gm_B)^2} > 1 \quad\Rightarrow\quad e > 1 \quad\Rightarrow$ hyperbolic orbit.

(b) $v_c = \sqrt{\dfrac{Gm_B}{r_c}}$, which agrees with Eq. (5.82)

5.140 $\Delta v = 3232\,\text{m/s}$

5.142 $Gm_e = 3.971\times 10^{14}\,\text{m}^3/\text{s}^2$

5.144 $r_g = 1.386\times 10^8\,\text{ft}$

$h_g = 1.177\times 10^8\,\text{ft}$

$v_c = 1.008\times 10^4\,\text{ft/s}$

5.146 $\Delta v = -3240\,\text{m/s} = -11{,}660\,\text{km/h}$

5.148 $\Delta v_P = 8064\,\text{ft/s} = 5498\,\text{mph}$ and $\Delta v_A = 4850\,\text{ft/s} = 3307\,\text{mph}$

$t = 18{,}930\,\text{s} = 5.258\,\text{h}$

5.150 Computer Problem

5.152 Concept Problem

5.154 **(a)** $v_\infty = \sqrt{\dfrac{r_P v_P^2 - 2Gm_B}{r_P}}$

(b) $r_P v_P^2 > 2Gm_B$

5.156 Concept Problem

5.158 Concept Problem

5.160 $Q_{\text{nz}} = 3.662\,\text{ft}^3/\text{s}$

$d = 2\sqrt{\dfrac{Q_{\text{nz}}}{v_w \pi}} = 0.2678\,\text{ft}$

5.162 $R = \frac{1}{4} p_A \pi d_A^2 + \dfrac{4\gamma Q^2}{\pi g}\left(\dfrac{1}{d_A^2} - \dfrac{1}{d_B^2}\right) = 2097\,\text{lb}$

5.164 $v_o = 269.6\,\text{m/s}$

5.166 $\mu_s = 0.07578$

5.168 $\dot{m}_{f1} = \frac{1}{2}\dot{m}_f(1 + \cos\theta)$ and $\dot{m}_{f2} = \frac{1}{2}\dot{m}_f(1 - \cos\theta)$

5.170 $\Delta v_x = -26.92\,\text{ft/s}$

5.172 $F_R = 270.4\,\text{kN}$

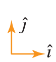
$M_O = F_R h = 20.28 \times 10^6\,\text{N}\cdot\text{m}$

5.174 $F = 1.099\,\text{lb}$

5.176 Computer Problem

5.178 $y_{\max} = 30{,}470\,\text{ft}$

5.180 $\left|\vec{F}_{\text{avg}}\right| = 1459\,\text{lb}$

5.182 $(\vec{v}_P)_{\text{final}} = (1.672\,\text{m/s})\,\hat{\imath}$, 

5.184 $\beta = 14.26°$

5.186 $M = \frac{1}{2} m\omega_0^2 r_0^2 \left(e^{2\omega_0 t} - e^{-2\omega_0 t}\right)$

5.188 $\Delta v = -2.919 \times 10^3\,\text{ft/s} = -1990\,\text{mph}$

5.190 $\Delta T_j = -4.160 \times 10^{10}\,\text{J}$

$\Delta T_e = -2.161 \times 10^{11}\,\text{J}$

$\Delta V = -5.153 \times 10^{11}\,\text{J}$

5.192 $(L - y)(\ddot{y} - g) - \frac{1}{2}\dot{y}^2 = 0$

Chapter 6

6.2 Concept Problem

6.4 Concept Problem

6.6 $\vec{\omega}_B = 532.2\,\hat{k}\ \text{rad/s}$ and $\vec{\alpha}_B = 187.8\,\hat{k}\ \text{rad/s}^2$

6.8 $\omega_B = \dfrac{R_A}{R_B}\omega_A = 600.0\,\text{rad/s}$

6.10 $t_{\text{stop}} = 87.94\,\text{s}$

$\Delta\theta_{\text{pt}} = 806.1\,\text{rev}$

6.12 $(\omega_{OA})_{\max} = 2.476\,\text{rad/s}$

6.14 $|\vec{\omega}_{\text{ram}}| = 0$

6.16 $\vec{v}_C = \big(71.88\,\hat{\imath} - 287.6\,\hat{\jmath} + 198.6\,\hat{k}\big)\ \text{cm/s}$

$\vec{a}_C = \big(7244\,\hat{\imath} + 4061\,\hat{\jmath} + 3260\,\hat{k}\big)\ \text{cm/s}^2$

6.18 $\vec{v}_C = \big(-43.13\,\hat{\imath} + 172.6\,\hat{\jmath} - 119.2\,\hat{k}\big)\ \text{cm/s}$

$\vec{a}_C = \big(2585\,\hat{\imath} + 1554\,\hat{\jmath} + 1110\,\hat{k}\big)\ \text{cm/s}^2$

6.20 $\vec{v}_D = \big(498.0\,\hat{\jmath} + 211.7\,\hat{k}\big)\ \text{cm/s}$

$\vec{a}_D = \big(-1.331\times10^4\,\hat{\imath} - 5341\,\hat{\jmath} + 1.237\times10^4\,\hat{k}\big)\ \text{cm/s}^2$

6.22 $\vec{\omega}_s = -10.00\,\hat{k}\ \text{rad/s}$

$\vec{\alpha}_s = -1.333\,\hat{k}\ \text{rad/s}^2$

6.24 $\vec{v}_G = (-0.1495\,\hat{u}_r - 3.379\,\hat{u}_\theta)\ \text{m/s}$

$\vec{a}_G = (-20.41\,\hat{u}_r - 3.660\,\hat{u}_\theta)\ \text{m/s}^2$

6.26 $\vec{v}_C = -(0.2917\,\hat{\imath} + 0.7361\,\hat{\jmath})\ \text{ft/s}$

$\vec{a}_C = (-0.2045\,\hat{\imath} + 0.08102\,\hat{\jmath})\ \text{ft/s}^2$

6.28 $\vec{v}_C = (-0.1791\,\hat{\imath} + 0.4920\,\hat{\jmath})\ \text{m/s}$

$\vec{a}_C = -(2.576\,\hat{\imath} + 0.9377\,\hat{\jmath})\ \text{m/s}^2$

6.30 $\vec{v}_H = \dfrac{r_A L}{r_C}\omega_A(-\sin\theta\,\hat{\imath} + \cos\theta\,\hat{\jmath})$

$$\vec{a}_H = \frac{r_A L}{r_C}\left[\left(-\alpha_A\sin\theta - \frac{r_A}{r_C}\omega_A^2\cos\theta\right)\hat{\imath} + \left(\alpha_A\cos\theta - \frac{r_A}{r_C}\omega_A^2\sin\theta\right)\hat{\jmath}\right].$$

6.32 $\omega_s = 72.72 \times 10^{-6}\,\text{rad/s}$

6.34 $\vec{\omega}_C = 40.00\,\hat{k}\,\text{rad/s}.$

$\vec{\alpha}_C = 5.200\,\hat{k}\,\text{rad/s}^2.$

6.36 Chain ring/sprocket combination: C1/S3.

$$\omega_w = \omega_s = \frac{R_c}{R_s}\omega_c = 126.4\,\text{rpm}$$

6.38 $\vec{v}_B = 146.0\,\hat{\jmath}\,\text{ft/s}$

6.40 $\vec{v}_B = (9.881\,\hat{\imath} + 3.666\,\hat{\jmath})\,\text{m/s}$

6.42 $\vec{\omega}_P = 9.600\,\hat{k}\,\text{rad/s}$

$\vec{v}_O = 2.000\,\hat{\imath}\,\text{ft/s}$

6.44 Concept Problem

6.46 $\vec{v}_A = -r\omega_d(\hat{\imath} + \hat{\jmath}),$

$\vec{v}_B = -2r\omega_d\,\hat{\jmath}.$

$\vec{v}_C = r\omega_d(\hat{\imath} - \hat{\jmath}).$

6.48 $\vec{\omega}_P = -1.600\,\hat{k}\,\text{rad/s}$

$\vec{v}_C = 5.333\,\hat{\imath}\,\text{m/s}$

6.50 $\vec{v}_C = (50.00\,\hat{\imath} + 50.00\,\hat{\jmath})\,\text{ft/s}$

$\vec{\omega}_{AB} = 20.00\,\hat{k}\,\text{rad/s}$

6.52 $\vec{\omega}_A = -7.000\,\hat{k}\,\text{rad/s}$

6.54 $\vec{\omega}_{AD} = 2.745\,\hat{k}\,\text{rad/s}$

6.56 $\vec{\omega}_{AD} = 1.373\,\hat{k}\,\text{rad/s}$

$\vec{v}_C = (-0.2745\,\hat{\imath} - 1.775\,\hat{\jmath})\,\text{m/s}$

6.58 $\vec{\omega}_{AB} = 2.208\,\hat{k}\,\text{rad/s}$

$\vec{v}_A = -2.274\,\hat{\jmath}\,\text{ft/s}$

6.60 $\vec{v}_A = 11.67\,\hat{\jmath}\,\text{ft/s}$

6.62 $\vec{v}_B = -\frac{2}{3}R\omega_{OA}\sin\theta\,\hat{\imath}.$

6.64 $\vec{\omega}_{AB} = -0.06805\,\hat{k}$ rad/s

6.66 $\dot{\phi} = -74.76$ rad/s

$\vec{v}_D = (-29.33\,\hat{\imath} + 73.73\,\hat{\jmath})$ ft/s

6.68 the cable is *unwinding* at 1.364 m/s.

6.70 $\vec{\omega}_{CD} = -0.8824\,\hat{k}$ rad/s

$\vec{\omega}_{BC} = -0.3000\,\hat{k}$ rad/s

$\vec{v}_C = (1.200\,\hat{\imath} + 0.3000\,\hat{\jmath})$ ft/s

6.72 $\vec{v}_B = -35.00\,\hat{\imath}$ ft/s

$\vec{v}_B = -35.00\,\hat{\imath}$ ft/s

6.74 $\vec{\omega}_{AB} = 3.333\,\hat{k}$ rad/s

$\vec{v}_C = 19.36\,\hat{\jmath}$ ft/s

6.76 $\vec{\omega}_s = -3.333\,\hat{k}$ rad/s

$\vec{v}_O = 5.000\,\hat{\imath}$ rad/s

6.78 $\vec{\omega}_{AB} = \vec{0}$ and $\vec{\omega}_{BC} = 7.667\,\hat{k}$ rad/s

6.80 $\vec{\omega}_{AB} = -\dfrac{R\dot{\theta}\sin(\beta+\theta)}{H\sin(\beta-\gamma)}\,\hat{k}$

$\vec{\omega}_{BC} = \dfrac{R\dot{\theta}\sin(\gamma+\theta)}{L\sin(\beta-\gamma)}\,\hat{k}$

6.82 $\vec{\omega}_{CD} = -12.00\,\hat{k}$ rad/s

$\vec{v}_{\text{bar}} = -3.000\,\hat{\imath}$ m/s

6.84 $\vec{\omega}_c = -877.1\,\hat{k}$ rad/s

6.86 $\vec{v}_B = \left[R\dot{\theta}\cos\theta - \dfrac{R\dot{\theta}(H - R\cos\theta)\sin\theta}{\sqrt{L^2 - (H - R\cos\theta)^2}}\right]\hat{\jmath}$

6.88 $\vec{\omega}_{BC} = -\dfrac{R\dot{\theta}\sin\theta}{\sqrt{L^2 - R^2\cos^2\theta}}\,\hat{k}$

$\vec{v}_C = \left(R\omega_{AB}\cos\theta + \dfrac{R^2\omega_{AB}\sin\theta\cos\theta}{\sqrt{L^2 - R^2\cos^2\theta}}\right)\hat{\jmath}$

6.90 $\vec{a}_C = (-12.86\,\hat{\imath} + 89.53\,\hat{\jmath})$ ft/s^2

6.92 $\dot{\theta} = 0$ and $\ddot{\theta} = -13.50$ rad/s^2

6.94 $\vec{\alpha}_{AD} = -4.620\,\hat{k}\ \text{rad/s}^2$

$\vec{\alpha}_{BD} = 5.650\,\hat{k}\ \text{rad/s}^2$

6.96 $\vec{\alpha}_{AD} = 1.590\,\hat{k}\ \text{rad/s}^2$

$\vec{a}_{B} = (0.9707\,\hat{\imath} - 1.674\,\hat{\jmath})\ \text{m/s}^2$

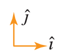
6.98 $\vec{\omega}_{C} = -378.6\,\hat{k}\ \text{rad/s}$

$\vec{\alpha}_{C} = -307{,}400\,\hat{k}\ \text{rad/s}^2$

6.100 $\vec{a}_{C} = -1024\,\hat{u}_r\ \text{ft/s}^2$

$\vec{a}_{P} = -3482\,\hat{u}_r\ \text{ft/s}^2$

6.102 $\vec{\omega}_{AB} = -0.4577\,\hat{k}\ \text{rad/s}$ and $\vec{\alpha}_{AB} = -0.2582\,\hat{k}\ \text{rad/s}^2$

6.104 $\vec{a}_{B} = -\frac{2}{3} R \left(\alpha_{OA} \sin\theta + \omega_{OA}^2 \cos\theta\right) \hat{\imath}.$ 

6.106 $\vec{\alpha}_{AB} = -27.08\,\hat{k}\ \text{rad/s}^2$ and $\vec{a}_{B} = -266.6\,\hat{\imath}\ \text{ft/s}^2$

6.108 $\vec{a}_{B} = 2R\left(\alpha_W - \dfrac{\omega_W^2}{\sqrt{5}}\right)\hat{\imath}$

6.110 $\vec{a}_{B} = -\dfrac{R}{32}\left[8\left(-4+\sqrt{2}\right)\alpha_W + \left(32 - 9\sqrt{2}\right)\omega_W^2\right]\hat{\imath}$

6.112 $\vec{\alpha}_{AB} = 0.2057\,\hat{k}\ \text{rad/s}^2$

6.114 $\vec{a}_{A} = \left(\dfrac{R\alpha_W}{\tan\theta} - \dfrac{R^2\omega_W^2}{L\sin^3\theta}\right)\hat{\jmath}$

6.116 $\vec{\alpha}_{BC} = 1639\,\hat{k}\ \text{rad/s}^2$

6.118 $\vec{\alpha}_{BC} = -\dfrac{HR\dot{\theta}^2\left(R^2 - H^2\right)\sin\theta}{\left(H^2 + R^2 - 2HR\cos\theta\right)^2}\,\hat{k}$

6.120 $\vec{a}_{Q} = 82.03\,\hat{u}_r\ \text{ft/s}^2$

6.122 $\vec{\alpha}_{OC} = -0.3714\,\hat{k}\ \text{rad/s}^2$

$\vec{a}_{P} = -(15.79\,\hat{u}_r + 6.539\,\hat{u}_\theta)\ \text{ft/s}^2$

6.124 $\vec{\alpha}_{\text{gate}} = 4.500\,\hat{k}\ \text{rad/s}^2$

6.126 $\vec{\alpha}_{BC} = -0.01749\,\hat{k}\ \text{rad/s}^2$ and $\vec{\alpha}_{CD} = 0.004516\,\hat{k}\ \text{rad/s}^2$

$\vec{a}_{C} = (0.003164\,\hat{\imath} - 0.03876\,\hat{\jmath})\ \text{ft/s}^2$

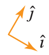
6.132 $\vec{\alpha}_{AB} = 87.67\,\hat{k}\ \text{rad/s}^2$ and $\vec{\alpha}_{BC} = -9.974\,\hat{k}\ \text{rad/s}^2$

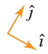
6.134 $\vec{a}_{P} = \left(\ddot{s} - s\omega_0^2\right)\hat{\imath} + \left(s\alpha_0 + 2\dot{s}\omega_0\right)\hat{\jmath}$

6.136 $\vec{a}_P = \left(\ddot{s} - s\omega_D^2\right)\hat{\imath} - \left(2\dot{s}\omega_D + d\omega_D^2\right)\hat{\jmath}$

$(\vec{a}_P)_{\text{Coriolis}} = -2\dot{s}\omega_D\,\hat{\jmath}$

6.138 $\vec{v}_D = (\dot{s} - d\omega_1)\,\hat{\imath} + s\,(\omega_1 - \omega_2)\,\hat{\jmath}$

6.140 $\vec{\omega}_{CD} = 22.43\,\hat{k}$ rad/s, 

$\vec{\alpha}_{CD} = -202.0\,\hat{k}$ rad/s^2. 

6.142 $\vec{\omega}_{AB} = 4.561\,\hat{k}$ rad/s, 

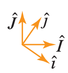
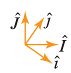
$\vec{\alpha}_{AB} = 18.43\,\hat{k}$ rad/s^2. 

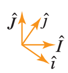
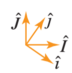
6.144 $\vec{a}_C = (-30.00\,\hat{\imath} + 51.80\,\hat{\jmath})$ ft/s^2

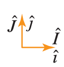
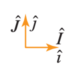
6.146 $\vec{v}_P = (-11.54\,\hat{\imath}_B + 33.30\,\hat{\jmath}_B)$ ft/s

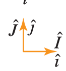
$\vec{a}_P = (-64.43\,\hat{\imath}_B - 16.43\,\hat{\jmath}_B)$ ft/s^2

6.148 $\vec{v}_D = [v_0 - d\omega_1 - R(\omega_1 - \omega_2)]\,\hat{\imath} + R(\omega_1 - \omega_2)\,\hat{\jmath}$

6.150 **(a)** $\vec{\omega}_{CD} = 2.513\,\hat{k}$ rad/s  and $\vec{v}_{\text{bar}} = 0.3016\,\hat{I}$ m/s 

(b) $\vec{\alpha}_{CD} = 37.90\,\hat{k}$ rad/s^2  and $\vec{a}_{\text{bar}} = 4.548\,\hat{I}$ m/s^2 

6.152 **(a)** $\vec{\omega}_{CD} = -6.283\,\hat{k}$ rad/s  and $\vec{v}_{\text{bar}} = -0.7540\,\hat{I}$ m/s 

(b) $\vec{\alpha}_{CD} = \vec{0}$ and $\vec{a}_{\text{bar}} = \vec{0}$ 

6.154 Computer Problem

6.156 $\vec{v}_C = \left(7.500\,\hat{\imath} + 7.506\,\hat{\jmath}\right)$ ft/s

$\vec{a}_C = \left(105.1\,\hat{\imath} - 161.0\,\hat{\jmath}\right)$ ft/s^2

6.158 $\dot{d}_{AB} = 1.118$ ft/s

$\ddot{d}_{AB} = 2.012$ ft/s^2

6.160 $\vec{v}_A = -R\omega_s\,\hat{\imath} + \ell\left(\omega_s + \dfrac{\dot{\ell}}{R}\right)\hat{\jmath}$

$$\vec{a}_A = -\left[\frac{\ell}{R^2}\left(\dot{\ell} + R\omega_s\right)^2 + R\dot{\omega}_s\right]\hat{\imath} + \left[\frac{1}{R}\left(\ell\ddot{\ell} + \dot{\ell}^2\right) - R\omega_s^2 + \ell\dot{\omega}_s\right]\hat{\jmath}$$

6.162 $v_C = 0.1601$ ft/s

6.164 $\vec{a}_D = \left[\ddot{s} - d\alpha_1 - s\,(\omega_1 - \omega_2)^2\right]\hat{\imath} + \left[2\,(\omega_1 - \omega_2)\,\dot{s} + s\,(\alpha_1 - \alpha_2) - d\omega_1^2\right]\hat{\jmath}$

6.166 $\vec{v}_D = (1.340\,\hat{\imath} + 5.000\,\hat{\jmath})\ \text{ft/s}$

6.168 $\vec{v}_A = 0.8750\,\hat{\jmath}\ \text{m/s},$

$\vec{a}_A = 0.3750\,\hat{\jmath}\ \text{m/s}^2,$

$\vec{v}_D = -1.750\,\hat{\jmath}\ \text{m/s}$

$\vec{a}_D = -0.7500\,\hat{\jmath}\ \text{m/s}^2.$

6.170 $\vec{\omega}_{\text{bar}} = -14.29\,\hat{k}\ \text{rad/s},$

6.172 $\vec{\omega}_{AC} = 2.442\,\hat{k}\ \text{rad/s}$

$\vec{\omega}_{CE} = -2.442\,\hat{k}\ \text{rad/s}$

$\vec{v}_E = (-15.00\,\hat{\imath} - 42.01\,\hat{\jmath})\ \text{ft/s}$

6.174 $\vec{v}_D = (v_C + \ell\omega_{OA}\sin\phi)\,\hat{\imath} + (d\omega_{OA} - \ell\omega_C\cos\phi)\,\hat{\jmath} - \ell\omega_C\sin\phi\,\hat{k}$

$$\vec{a}_D = \left(2\ell\omega_C\omega_{OA}\cos\phi + \ell\alpha_{OA}\sin\phi - d\omega_{OA}^2\right)\hat{\imath} + \left[d\alpha_{OA} + 2v_C\omega_{OA} + \ell\left(\omega_C^2 + \omega_{OA}^2\right)\sin\phi\right]\hat{\jmath} - \ell\omega_C^2\cos\phi\,\hat{k}$$

6.176 $\vec{v}_C = (21.50\,\hat{\imath} + 7.506\,\hat{\jmath})\ \text{ft/s} = \left(21.50\,\hat{I} + 7.506\,\hat{J}\right)\ \text{ft/s}$

$\vec{a}_C = (105.1\,\hat{\imath} + 165.7\,\hat{\jmath})\ \text{ft/s}^2 = \left(105.1\,\hat{I} + 165.7\,\hat{J}\right)\ \text{ft/s}^2$

Chapter 7

7.2 $t_{\text{stop}} = 1.863\ \text{s}$

$d_{\text{stop}} = 16.77\ \text{ft}$

7.4 $h_{\max} = 4.054\ \text{ft}$ and $a_{Gx} = 9.800\ \text{ft/s}^2$

7.6 $a_0 = 15.70\ \text{ft/s}^2$

7.8 Concept Problem

7.10 $a_0 = 66.80\ \text{ft/s}^2$

7.12 $P = 20.70\ \text{lb}$

$N_A = 152.1\ \text{lb}$

$N_B = 147.9\ \text{lb}$

7.14 $\vec{a}_C = -2.875\,\hat{\jmath}\ \text{m/s}^2.$

7.16 $L = 5.604\times10^5\ \text{N}$

7.18 $a_{Gx} = 2.147\ \text{ft/s}^2$ and $P = 49.83\ \text{lb}$

7.20 $\theta = 17.00°$ and $\phi = 17.00°$

7.22 $N = 1.492 \times 10^5\,\mathrm{N}$

$\delta = 1.909\,\mathrm{m}$

7.24 $N_f = 783.7\,\mathrm{lb}$

$N_r = 783.2\,\mathrm{lb}$

$N_B = 2233\,\mathrm{lb}$

$H = 673.7\,\mathrm{lb}$

$F = 576.9\,\mathrm{lb}$

$(\mu_s)_{\mathrm{min}} = 0.7362$

7.26 $\phi = \tan^{-1}\left(\frac{a_A}{g}\right)$

$\theta = \tan^{-1}\left(\frac{a_A}{g}\right)$

7.28 $R_x = -0.1115t^2\,\mathrm{N/s^2}$,

$R_y = 0.010\,12\,\mathrm{N}$,

$M_z = 3.110 \times 10^{-5}\,\mathrm{N{\cdot}m}$

7.30 $t_f = 1.411\,\mathrm{s}$

$n = 7.485\,\mathrm{rev}$ (cw)

7.32 $\vec{\alpha}_d = -10.06\,\hat{k}\,\mathrm{rad/s^2}$.

$n = 16.01\,\mathrm{rev}$ (cw)

7.34 $\omega_f = 31.42\,\mathrm{rad/s} = 300.0\,\mathrm{rpm}$

7.36 $M_z = 3208\,\mathrm{ft{\cdot}lb}$

7.38 $\vec{F}_A = 9.197\,(-\hat{\imath} + \hat{\jmath})\,\mathrm{N}$

$\vec{F}_B = 9.197\,(\hat{\imath} - \hat{\jmath})\,\mathrm{N}$

$t_s = 4.096\,\mathrm{s}$

7.40 $\mu_k = 1.443$

$\vec{F}_A = (-18.83\,\hat{\imath} + 26.19\,\hat{\jmath})\,\mathrm{N}$ and $\vec{F}_B = (18.83\,\hat{\imath} - 11.48\,\hat{\jmath})\,\mathrm{N}$

7.42 $O_r = -16.85\,\mathrm{lb}$ and $O_\theta = -5.000\,\mathrm{lb}$

7.44 $|\alpha_{\mathrm{max}}| = \frac{\sqrt{3}g}{L}$ for $\ell = \frac{1}{6}\left(3 \pm \sqrt{3}\right)L$

7.46 $\dot{\phi} = 1.503\,\mathrm{rad/s}$

7.48 $$D_x = \frac{3m_c gh\left[2(d-\ell)m_c + (2d-L)m_p\right]}{\left[w^2+4h^2+12(d-\ell)^2\right]m_c + 4\left(3d^2-3dL+L^2\right)m_p}$$

$$D_y = g\,\frac{L^2m_p^2+\left(4h^2+w^2\right)m_c^2+\left[4h^2+w^2+4\left(L^2-3\ell L+3\ell^2\right)\right]m_c m_p}{4\left(3d^2-3dL+L^2\right)m_p+\left[4h^2+w^2+12(d-\ell)^2\right]m_c}$$

$$\alpha_p = \alpha_c = \frac{6g\left[2(\ell-d)m_c+(L-2d)m_p\right]}{4\left(3d^2-3dL+L^2\right)m_p+\left[4h^2+w^2+12(d-\ell)^2\right]m_c}$$

7.50 $$F_f = \frac{3}{2}mg\cos\theta\left(\frac{3}{2}\sin\theta-1\right)$$

$$N = \frac{1}{4}mg\,(1-3\sin\theta)^2$$

$$(\mu_s)_{\min} = \infty$$

7.52 $$\alpha_T = -6.925\,\hat{k}\ \mathrm{rad/s^2}$$

$$\vec{F}_O = (-1323\,\hat{\imath}+48.47\,\hat{\jmath})\ \mathrm{N}$$

7.54 $\vec{F}_A = (-35.07\,\hat{\imath}+48.22\,\hat{\jmath})\ \mathrm{N}$ and $\vec{\alpha}_b = -6.679\,\hat{k}\ \mathrm{rad/s^2}$

7.56 $\vec{F}_B = (-560.1\,\hat{\imath}+558.6\,\hat{\jmath})\ \mathrm{N}$ and $M_B = -423.8\,\hat{k}\ \mathrm{N{\cdot}m}$

7.58 $F = \dfrac{k_G^2}{k_G^2+r^2}mg\sin\theta$, $N = mg\cos\theta$, and $\alpha_b = -\dfrac{rg\sin\theta}{k_G^2+r^2}$

$$(\mu_s)_{\min} = \frac{k_G^2}{k_G^2+r^2}\tan\theta$$

7.60 $\vec{a}_G = -\mu_k g\,\hat{\imath}$ and $\vec{\alpha}_b = -\dfrac{gr\mu_k}{k_G^2}\,\hat{k}.$

7.62

7.64 $T_{CD} = 147.2\ \mathrm{N}$, and $\vec{a}_G = -4.905\,\hat{\jmath}\ \mathrm{m/s^2}$

7.66 $\vec{F}_s = \left(\dfrac{R^2}{R^2+k_G^2}\right)P\,\hat{\imath}+(mg-P)\,\hat{\jmath}$ and $\vec{\alpha}_s = -\dfrac{PR}{m(R^2+k_G^2)}\,\hat{k}.$

7.68 Notice that the sign of the angular acceleration α_c contradicts our assumption that the crate tips and slips, since the only physically meaningful tipping would be in the clockwise direction. Therefore, this solution shows that the crate cannot tip and slip.

7.70 $$\theta_{\mathrm{sep}} = \frac{\pi}{3} = 60.00^\circ$$

7.72 $$F = 12.13\ \mathrm{lb}$$

$$\left(t_f\right)_{\mathrm{new}} = 6.845\ \mathrm{s}$$

7.74 $$\vec{\alpha}_{AB} = \frac{6m_{AB}\,g\cos\theta}{L\left(4m_{AB}+18m_B\sin^2\theta\right)}\,\hat{k}$$

$$\vec{a}_B = \frac{6m_{AB}\,g\sin\theta\cos\theta}{4m_{AB}+18m_B\sin^2\theta}\,\hat{\imath}$$

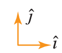
$$\vec{\alpha}_w = -\frac{6m_{AB}\,g\sin\theta\cos\theta}{R\left(4m_{AB}+18m_B\sin^2\theta\right)}\,\hat{k}$$

7.76 $$\vec{\alpha}_{AB} = \frac{6g(2m_A + m_{AB})\cos\theta}{2L\left(6m_A\cos^2\theta + 2m_{AB} + 9m_B\sin^2\theta\right)}\,\hat{k}$$

$$\vec{a}_B = \frac{6g(2m_A + m_{AB})\sin\theta\cos\theta}{2\left(6m_A\cos^2\theta + 2m_{AB} + 9m_B\sin^2\theta\right)}\,\hat{\imath}$$

$$\vec{\alpha}_w = -\frac{6g(2m_A + m_{AB})\sin\theta\cos\theta}{2R\left(6m_A\cos^2\theta + 2m_{AB} + 9m_B\sin^2\theta\right)}\,\hat{k}$$

7.78 $I_G = mR^2$

7.80 $\vec{\alpha}_b = -\dfrac{6g\sin\theta}{L\left(1+3\sin^2\theta\right)}\,\hat{k}$, $\vec{F}_A = \dfrac{mg}{1+3\sin^2\theta}\,\hat{\jmath}$, and $\vec{a}_A = \dfrac{3g\sin\theta\cos\theta}{1+3\sin^2\theta}\,\hat{\imath}$. 

7.82 Computer Problem

7.84 Computer Problem

7.86 $m\left(1 + \dfrac{k_G^2}{r^2}\right)\ddot{x} + kx = mg\sin\theta + kL_0$

7.88 $\theta = \cos^{-1}\left(\dfrac{2}{3}\right) = 48.19^\circ$

7.90 $\vec{F}_{\text{due to bowl}} = -mg\cos\phi\,\hat{u}_r + \frac{2}{7}mg\sin\phi\,\hat{u}_\phi$

$$\vec{\alpha}_b = \frac{5g\sin\phi}{7\rho}\,\hat{k}$$

$$\vec{a}_G = -\tfrac{5}{7}g\sin\phi\,\hat{u}_\phi$$

7.92 $\dfrac{7}{5}(R-\rho)\ddot{\phi} + g\sin\phi = 0$

7.94 $h = \frac{7}{5}r$

7.96 Computer Problem

7.98 $\vec{a}_A = \dfrac{60g}{181}\,\hat{\imath}$ and $\vec{\alpha}_b = \dfrac{45g}{181R}\,\hat{k}$

7.100 Computer Problem

7.102 $T_{CD} = 2061\,\text{lb}$, and $\vec{a}_E = -5.655\,\hat{\jmath}\ \text{ft/s}^2$

7.104 $\vec{a}_E = (13.19\,\hat{\imath} - 25.90\,\hat{\jmath})\ \text{ft/s}^2$

$A_x = 436.6\,\text{lb}$ and $A_y = 255.6\,\text{lb}$

$C_x = 628.8\,\text{lb}$ and $C_y = 353.5\,\text{lb}$

7.106 $A_x = 228.7\,\text{lb}$, $A_y = 1330\,\text{lb}$, $C_x = 336.2\,\text{lb}$, and $C_y = 1940\,\text{lb}$

$\vec{a}_E = (6.996\,\hat{\imath} + 7.059\,\hat{\jmath})\ \text{ft/s}^2$

7.108 $P_{\text{max}} = 1595\,\text{lb}$

7.110 $\vec{a}_G = -\mu_k g\,\hat{\imath}$ and $\vec{\alpha}_b = -\dfrac{\mu_k r g}{k_G^2}\,\hat{k}$

7.112 $\theta = \tan^{-1}\left(\dfrac{v_c^2}{gR}\right)$

7.114 $\vec{\alpha}_{AC} = 1.459\,\hat{k}\ \text{rad/s}^2$ and $\vec{\alpha}_{CE} = -1.459\,\hat{k}\ \text{rad/s}^2$.

7.116 Computer Problem

7.118

$$N = \frac{\left(2k_G^2 + 2R^2 + \rho^2\right)\cos\theta - \rho^2\cos(\theta - 2\phi) - \rho R\left[\sin(2\theta - \phi) - 3\sin\phi\right]}{2\left[k_G^2 + R^2 + \rho^2 - 2\rho R\sin(\theta - \phi)\right]}W + \frac{\rho\left[\rho R\cos(2\theta - 2\phi) - 3\rho R + 2\left(k_G^2 + R^2 + \rho^2\right)\sin(\theta - \phi)\right]\dot{\phi}^2}{2g\left[k_G^2 + R^2 + \rho^2 - 2\rho R\sin(\theta - \phi)\right]}W$$

$$F = \frac{k_G^2\sin\theta + \rho\cos(\theta - \phi)\left(R\cos\theta + \rho\sin\phi\right)}{k_G^2 + R^2 + \rho^2 - 2\rho R\sin(\theta - \phi)}W - \frac{\rho\left[k_G^2 + \rho^2 - \rho R\sin(\theta - \phi)\right]\dot{\phi}^2\cos(\theta - \phi)}{g\left[k_G^2 + R^2 + \rho^2 - 2\rho R\sin(\theta - \phi)\right]}W$$

$$\ddot{\phi} = \frac{g\left(R\sin\theta - \rho\cos\phi\right) - \rho R\dot{\phi}^2\cos(\theta - \phi)}{k_G^2 + R^2 + \rho^2 - 2\rho R\sin(\theta - \phi)}$$

7.120

$$L\left(m_{AB} + 2m_C\right)\dot{\theta}^2\sin\theta + (2d + h)\,m_C\dot{\phi}^2\sin\phi + 2\left(m_{AB} + m_C\right)\ddot{x}_A = L\left(m_{AB} + 2m_C\right)\ddot{\theta}\cos\theta + (2d + h)\,m_C\ddot{\phi}\cos\phi$$

$$4\left(m_{AB} + 2m_C\right)gL\sin\theta + \left(m_{AB} + 2m_C\right)L^2\dot{\theta}^2\sin 2\theta + m_C\,(2d + h)\,L\Big[3\sin(\theta - \phi) + \sin(\theta + \phi)\Big]\dot{\phi}^2 + 8I_D\ddot{\theta} - 4m_C L\ddot{x}_A\cos\theta + \Big[m_{AB} + 6m_C - \left(m_{AB} + 2m_C\right)\cos 2\theta\Big]L^2\ddot{\theta} + 2\,(2d + h)\,m_C L\big(\cos\theta\cos\phi + 2\sin\theta\sin\phi\big)\ddot{\phi} = 0$$

$$2\,(2d + h)\,m_C\Big[g\sin\phi - L\dot{\theta}^2\sin(\theta - \phi) - \ddot{x}_A\cos\phi + L\ddot{\theta}\cos(\theta - \phi)\Big] + \Big[4I_E + (2d + h)^2 m_C\Big]\ddot{\phi} = 0$$

7.122 $P_{\max} = \mu_s g\left[m_d + m_c\left(1 + \dfrac{R^2}{k_G^2}\right)\right]$, $\vec{a}_C = \mu_s g\left(1 + \dfrac{R^2}{k_G^2}\right)\hat{\imath}$, and $\vec{a}_G = \mu_s g\,\hat{\imath}$

7.124 $P = 7.588\ \text{N}$ and $(\mu_s)_{\min} = 0.04620$

Chapter 8

8.2 Concept Problem

8.4 Concept Problem

8.6 $T = 0.011\,21\ \text{J}$

8.8 $T = 1719\ \text{J}$

$h = 17.52\ \text{m}$

8.10 $\omega_{b2} = 3.693\ \text{rad/s}$

8.12 $\theta_{\min} = 53.13°$

8.14 $\Delta\theta = 8781\ \text{rev}$

8.16 $k = 472.0\ \text{lb/ft}$

8.18 $\theta_1 = 33.02°$

8.20 $\omega_{d2} = \sqrt{\dfrac{(2Md/R) - kd^2}{m(k_G^2 + R^2)}}$

$d_s = \dfrac{2M}{kR}$

8.22 $M = 653.8\,\text{N·m}$

8.24 $v_c = 3.040\,\text{m/s}$

8.26 $P = 2.344\,\text{N}$

8.28 $d = 0.4990\,\text{m}$ and $d = 1.102\,\text{m}$

8.30 $L_f = 34.13\,\text{ft}$

8.32 $\omega_{s2} = 2.640\,\text{rad/s}$

8.34 $(U_{1\text{-}2})_{\text{nc}} = -2042\,\text{ft·lb}$

8.36 $v_{G2} = 3.951\,\text{ft/s}$

8.38 $v_{\text{person}} = \sqrt{2gH(1+\cos\theta)}$ and $v_{\text{person}}\big|_{\theta=0°} = 10.85\,\text{m/s}$

8.40 $T = 15.85\,\text{ft·lb}$

8.42 $v_c = 6.291\,\text{ft/s}$

8.44 $v_{A2} = 2.709\,\text{ft/s}$ and $v_{B2} = 5.417\,\text{ft/s}$

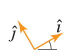
8.46 $\omega_{s2} = 1.094\,\text{rad/s}$

8.48 $T = 28.88\,\text{ft·lb}$

8.50 $v_{Q2} = 20.45\,\text{ft/s}$

8.52 $n_{\text{min}} = 26$

$v_{\text{person}} = 26.54\,\text{ft/s}$

8.54 $\vec{\omega}_d = \sqrt{\dfrac{d[(2M/R) + 2mg\sin\theta - dk]}{m(R^2 + k_G^2)}}\,\hat{k}.$  @ θ

$M = 11.25\,\text{ft·lb}$

8.56 $\delta = 1.031\,\text{ft}$

8.58 $m_C = 26.96\,\text{kg}$

8.60 $v_{S2} = 16.00\,\text{ft/s}$

8.62 $W_P = 799.5\,\text{lb}$

8.64 $v_C = 5.019\,\text{m/s}$ and $\vec{\omega}_D = (44.61\,\text{rad/s})\,\hat{k}$

8.66 $v_{\text{max}} = 6.389\,\text{ft/s}$

8.68 $(v_B)_{\text{final}} = 1.279\,\text{m/s}$

8.70 **(a)** $a_{Gx} = \frac{1}{2}L(\ddot{\theta}\cos\theta - \dot{\theta}^2\sin\theta)$ and $a_{Gy} = -\frac{1}{2}L(\ddot{\theta}\sin\theta + \dot{\theta}^2\cos\theta)$

$F = \frac{1}{2}mL(\ddot{\theta}\cos\theta - \dot{\theta}^2\sin\theta)$ and $N = mg\left[1 - \dfrac{L}{2g}(\ddot{\theta}\sin\theta + \dot{\theta}^2\cos\theta)\right]$

(b) $\dot{\theta}^2 = \dfrac{3g}{L}(1-\cos\theta)$ and $\ddot{\theta} = \dfrac{3g}{2L}\sin\theta$

(c) $F = \frac{3}{4}mg\sin\theta(3\cos\theta - 2)$ and $N = \frac{1}{4}mg(1-3\cos\theta)^2$

$(\mu_s)_{\text{max}} = 0.3706$ and $\theta_{\text{slide}} = 35.10°$

8.72 Computer Problem

8.74 Computer Problem

8.76 Concept Problem

8.78 Concept Problem

8.80 $\vec{p}_w = (-83.85\,\text{lb·s})\,\hat{\imath}$

$\vec{h}_C = (310.3\,\text{ft·lb·s})\,\hat{k}$

8.82 $|\vec{\omega}_{r2}| = 77.59\,\text{rpm}$

8.84 $P = 25.00\,\text{N}$

8.86 $k_G = 5.218\,\text{ft}$

8.88 $(\vec{h}_A)_{AB} = \dfrac{1}{3}m_{AB}R^2\omega_{AB}\,\hat{k} = (1.725\,\text{kg·m}^2/\text{s})\,\hat{k},$

$(\vec{h}_A)_{BC} = m_{BC}\omega_{AB}R^2\,\hat{k} = (7.200\,\text{kg·m}^2/\text{s})\,\hat{k},$

$(\vec{h}_D)_{CD} = \frac{1}{3}m_{CD}HR\omega_{AB}\,\hat{k} = (7.750\,\text{kg·m}^2/\text{s})\,\hat{k},$

8.90 $(\vec{h}_C)_W = (91.88\times10^{-6}\,\text{kg·m}^2/\text{s})\,\hat{k},$ $\hat{u}_\theta$ $\hat{u}_r$ @ θ

$(\vec{h}_O)_W = (669.4\times10^{-6}\,\text{kg·m}^2/\text{s})\,\hat{k},$ $\hat{u}_\theta$ $\hat{u}_r$ @ θ

8.92 $|\vec{p}_{AB}| = \dfrac{W_{AB}v_A}{2g\cos\theta} = 3.227\,\text{lb·s}$

$\vec{h}_G = \dfrac{W_{AB}Lv_A}{12g\cos\theta}\,\hat{k} = (2.420\,\text{ft·lb·s})\,\hat{k},$

8.94 $\Delta t = 16.98\,\text{s}$

8.96 $|\vec{\omega}_{s2}| = 2.470\,\text{rad/s}$

8.98 **(a)** Collar modeled as a particle: $v_{\text{impact}} = 0.9905\,\text{ft/s}$,
(b) Collar modeled as a rigid body: $v_{\text{impact}} = 0.9432\,\text{ft/s}$,

8.100 $|\omega_A|_{\text{after slip stops}} = |\omega_B|_{\text{after slip stops}} = 18.70\,\text{rad/s}$

8.102 $v_{C2} = 25.19\,\text{m/s}$

8.104 $v_f = 18.34\,\text{ft/s}$ and $t_r = 2.502\,\text{s}$

8.106 Concept Problem

8.108 $v_G\big|_{t=3\,\text{s}} = 7.563\,\text{m/s}$
$(\mu_s)_{\min} = 0.3951$

8.110 $\omega_f = 30.13\,\text{rpm}$

8.112 $d = \dfrac{4r^2 b}{(2r-b)^2}$

8.114 **(a)** $\vec{v}_A = R\omega_s\,\hat{\imath} + \ell\left(\omega_s + \dfrac{\dot{\ell}}{R}\right)\hat{\jmath}$

(b) $\frac{1}{2}\left(I_O + 2mR^2\right)\omega_0^2 = m\left[R^2\omega_s^2 + \ell^2\left(\omega_s + \dfrac{\dot{\ell}}{R}\right)^2\right] + \frac{1}{2}I_O\omega_s^2$

(c) $\left(I_O + 2mR^2\right)\omega_0 = \left[I_O + 2m(\ell^2 + R^2)\right]\omega_s + 2m\dfrac{\ell^2}{R}\dot{\ell}$

(d) $\dot{\ell} = R\omega_0$ and $\omega_s = \dfrac{I_O + 2m(R^2 - \ell^2)}{I_O + 2m(R^2 + \ell^2)}\omega_0$

$\ell\big|_{\omega_s = 0} = \sqrt{\dfrac{I_O}{2m} + R^2}$

(e) $\ell(t) = R\omega_0 t$

$\omega_s(t) = \dfrac{I_O + 2mR^2(1 - \omega_0^2 t^2)}{I_O + 2mR^2(1 + \omega_0^2 t^2)}\omega_0$

8.116 $\vec{v}_P^{\,+} = (5.682\,\text{ft/s})\,\hat{\imath}$ and $\vec{v}_Q^{\,+} = (-6.198\,\text{ft/s})\,\hat{\imath}$. $\hat{\jmath}$ $\hat{\imath}$

8.118 $v_0 = 1.397\,\text{ft/s}$

8.120 $v_0 = 1326\,\text{ft/s}$

8.122 $d = 2.094\,\text{ft}$

$v_b^+ = 226.1\,\text{ft/s}$ and $\vec{\omega}_B = (-26.60\,\text{rad/s})\,\hat{k}$. $\hat{\jmath}$ $\hat{\imath}$

8.124 $\theta_{\text{swept}} = 220.0^\circ$

8.126 $\vec{v}_G^{\,+} = (-1.310\,\text{m/s})\,\hat{\imath}$ and $\vec{\omega}_A^{\,+} = (3.434\,\text{rad/s})\,\hat{k}$. $\hat{\jmath}$ $\hat{\imath}$

8.128 $d = 5.525\,\text{m}$

8.130 $\vec{\omega}_A^{\,+} = (1.796\,\text{rad/s})\,\hat{k}$ and $\vec{\omega}_B^{\,+} = (-0.4047\,\text{rad/s})\,\hat{k}$. $\hat{\jmath}$ $\hat{\imath}$ @ -12°

8.132 Concept Problem

8.134 $T = 0.025\,70\,\text{ft·lb}$

8.136 $v_{B2} = 0.4069\,\text{ft/s}$

8.138 $\vec{h}_D = (14.90\,\text{ft·lb·s})\,\hat{k}.$

8.140 $|\omega_A|_{\text{after slip stops}} = |\omega_B|_{\text{after slip stops}} = |\omega_C|_{\text{after slip stops}} = 16.41\,\text{rad/s}$

8.142 $(v_0)_{\max} = 2.176\,\text{m/s}$

8.144 $v_{Gy}^{+} = -1.431\,\text{ft/s}$ and $\vec{\omega}_p^{+} = (-0.3211\,\text{rad/s})\,\hat{k}.$

Chapter 9

9.2 $I_O = \dfrac{mgL\tau^2}{4\pi^2}$ or $I_G = \dfrac{mgL\tau^2}{4\pi^2} - mL^2$

9.4 $\tau = 2\pi\sqrt{\dfrac{7L}{6g}}$

9.6 $\omega_n = \sqrt{\dfrac{Gr^4}{\rho L R^4 t}}$

9.8 $\ell = \sqrt{\dfrac{I_G}{m}}$

9.10 $f = 1.771\,\text{Hz}$

9.12 $f = \dfrac{\omega_n}{2\pi} = \dfrac{d}{4}\sqrt{\dfrac{\rho g}{\pi m}} = 0.5663\,\text{Hz}$

9.14 $\tau = \dfrac{2\pi d}{h}\sqrt{\dfrac{m}{k}}$

9.16 $\tau = 2\pi\sqrt{\dfrac{\frac{1}{3}\rho\left(h^3 + d^3\right) + md^2}{\left(k - \frac{1}{2}\rho g\right)h^2}}$

9.18 $m\ddot{y} + ky = 0$

$m\ddot{\theta} + k\theta = 0$

9.20 $\ddot{x}_G + \dfrac{17k}{6m}x_G = 0$

9.22 moving the disk up $n = 4.778$ turns

9.24 $\ddot{x}_G + \dfrac{8k}{3m}x_G = 0$

$\tau = 2.221\,\text{s}$

9.26 $\omega_n = \sqrt{\dfrac{2g}{3(R-r)}}$

$\tau = 2\pi\sqrt{\dfrac{3(R-r)}{2g}}$

9.28 $\tau = 2\pi\sqrt{\dfrac{L}{2g}}$

9.30 $\tau = 2\pi\sqrt{\dfrac{(3\pi - 2)R}{3g}}$

9.32 $x(t) = A\sin\omega_n t + B\cos\omega_n t + \dfrac{F_0/k}{1-(\omega_0/\omega_n)^2}\cos\omega_0 t$

9.34
$$m_u = 0.01\,\text{kg} \quad\Rightarrow\quad |y_m| = \sqrt{2.190\times10^{-6}\cos(4.369t) + 1.888\times10^{-5}}\,\text{m},$$
$$m_u = 0.1\,\text{kg} \quad\Rightarrow\quad |y_m| = \sqrt{1.100\times10^{-5}\cos(4.369t) + 1.112\times10^{-5}}\,\text{m},$$
$$m_u = 1\,\text{kg} \quad\Rightarrow\quad |y_m| = \sqrt{9.798\times10^{-4}\cos(4.369t) + 1.014\times10^{-3}}\,\text{m}$$

9.36 $\theta_{\text{amp}} = 0.001\,758\,\text{rad}$

9.38 Concept Problem

9.40 $x(t) = \left(0.000\,501\,3\sin 10t + 0.1000\cos 10t - 2.506\times10^{-5}\sin 200t\right)\text{m}$

9.42 $m\ddot{y} + 2k\left(1 - \dfrac{L_0}{L}\right)y = F_0\sin\omega_0 t$

$$y(t) = \frac{F_0/k_{\text{eq}}}{1-(\omega_0/\omega_n)^2}\left[\sin\omega_0 t - \frac{\omega_0}{\omega_n}\sin\omega_n t\right],$$

where $k_{\text{eq}} = 2k\left(1 - \dfrac{L_0}{L}\right)$ and $\omega_n = \sqrt{\dfrac{2k}{m}\left(1 - \dfrac{L_0}{L}\right)}$

9.44 $\left(\tfrac{2}{3}m_B + \tfrac{1}{2}m_A\right)\ddot{x}_A + 2kx_A = \tfrac{1}{2}F_0\sin\omega_0 t$

$$(x_A)_{\text{amp}} = \frac{F_0}{4k - \left(\frac{4}{3}m_B + m_A\right)\omega_0^2}$$

9.46 $\omega_n = \sqrt{\dfrac{3gEI}{(W_u + W_e)\,d^3}} = 505.7\,\text{rad/s}$

$$f = \frac{\omega_n}{2\pi} = 80.48\,\text{Hz}$$

$$MF = \frac{|\theta_p|\,(W_u + W_e)\,d}{W_u R} = \frac{(\omega_p/\omega_n)^2}{1-(\omega_p/\omega_n)^2} = 0.2071$$

9.48 Concept Problem

9.50 Concept Problem

9.52 no peak in MF for $\zeta \geq \sqrt{1/2}$

9.54 $\ddot{y} + 2\zeta\omega_n\dot{y} + \omega_n^2 y = \dfrac{m_u\varepsilon\omega_r^2}{m}\sin\omega_r t$, where $c/m = 2\zeta\omega_n$ and $k/m = \omega_n^2$

9.56 $F_0 = 0.015\,84\,\text{N}$

$|y| = 0.000\,094\,10\,\text{m}$

9.58 $y(t) = \left(0.5te^{-28.28t}\right)\text{m}$

9.60 $\zeta = \dfrac{1}{10} = 0.1 \quad \text{for } MF = 5$

$$\zeta = \frac{1}{20} = 0.05 \quad \text{for } MF = 10$$

9.62 $mL\ddot{\theta} + 0.18cL\dot{\theta} + (mg + 0.72kL)\,\theta = 0$

$$\omega_d = \sqrt{\frac{g}{L} + 0.72\frac{k}{m} - 0.0081\frac{c^2}{m^2}}$$

9.64

$$\begin{aligned} y_A = &-\frac{\omega_0 E\left[2k\left(k - m_A\omega_0^2\right) + c^2\omega_0^2\right]}{2\omega_d\left[\left(k - m_A\omega_0^2\right)^2 + c^2\omega_0^2\right]} e^{-(c/2m_A)t}\sin\omega_d t \\ &+ \frac{m_A c\omega_0^3 E}{\left(k - m_A\omega_0^2\right)^2 + c^2\omega_0^2} e^{-(c/2m_A)t}\cos\omega_d t \\ &+ \frac{m_A\omega_0^2 E}{\left(k - m_A\omega_0^2\right)^2 + c^2\omega_0^2}\left[\left(k - m_A\omega_0^2\right)\sin\omega_0 t - c\omega_0\cos\omega_0 t\right] + E\sin\omega_0 t \\ = &-0.0002665\cos(94.25t) + e^{-2.500t}\left[0.0002665\cos(5.204t) + 0.0002121\sin(5.204t)\right] \\ &- 4.642\times10^{-6}\sin(94.25t) \end{aligned}$$

9.66 $D = 4.373\times10^{-6}\,\text{m}$

9.68 $m\ddot{s} + c\dot{s} + ks = mA\omega_0^2\sin\omega_0 t, \quad \text{where} \quad s(t) = y(t) - u(t)$

$$y(t) = \left[\frac{mA\omega_0^2\left(k - m\omega_0^2\right)}{\left(k - m\omega_0^2\right)^2 + c^2\omega_0^2} + A\right]\sin\omega_0 t - \left[\frac{mcA\omega_0^3}{\left(k - m\omega_0^2\right)^2 + c^2\omega_0^2}\right]\cos\omega_0 t$$

$$\text{DT} = \sqrt{\frac{k^2 + c^2\omega_0^2}{\left(k - m\omega_0^2\right)^2 + c^2\omega_0^2}}$$

9.70 $m\ddot{x} + \dfrac{k_1 k_2}{k_1 + k_2}\,x = 0$

9.72 $\Delta k = -5.910\%$

9.74 $(y_c)_{\text{amp}} = 0.000\,454\,4\,\text{m} = 0.4544\,\text{mm}$

9.76 $F_0 = 200.1\,\text{N}$

$$|\ddot{x}| = 282.0\,\text{m/s}^2$$

9.78

$$\begin{aligned} m_u &= 0.01\,\text{kg}: & F_t &= 14.77\sin(125.7t + 0.8422) + 17.67\cos(125.7t + 0.8422)\,\text{N}, \\ m_u &= 0.1\,\text{kg}: & F_t &= 147.7\sin(125.7t + 0.8422) + 176.7\cos(125.7t + 0.8422)\,\text{N}, \\ m_u &= 1\,\text{kg}: & F_t &= 1477\sin(125.7t + 0.8422) + 1767\cos(125.7t + 0.8422)\,\text{N} \end{aligned}$$

9.80 $m\ddot{y} + 2k\left(1 - \dfrac{L_0}{\sqrt{y^2 + L^2}}\right)y = 0$

9.82 $m\ddot{y} + 2k\left(1 - \dfrac{L_0}{L}\right)y = 0$

Chapter 10

10.2 $\vec{v}_B = \ell\left(-\omega_1 \sin\theta\,\hat{\imath} + \omega_1\cos\theta\,\hat{\jmath} + \dot{\theta}\cos\theta\,\hat{k}\right)$

$\vec{a}_B = -\ell\left(\dot{\theta}^2\cos\theta - \omega_1^2\cos\theta - \dot{\omega}_1\sin\theta\right)\hat{\imath} + \ell\left(\dot{\omega}_1\cos\theta - \omega_1^2\sin\theta\right)\hat{\jmath} + \ell\ddot{\theta}\cos\theta\,\hat{k}$

10.4 $\vec{v}_A = 2(\ell + d)\omega_1\cos^2\theta$

$\vec{a}_A = -2(\ell+d)\omega_1^2\cos^2\theta\,\hat{\imath} + 2(\ell+d)\dot{\omega}_1\cos^2\theta\,\hat{\jmath} - (\ell+d)\omega_1^2\cos\theta$

10.6 $\vec{v}_E = R\omega_{\text{arm}}\cos\gamma\,\hat{\imath} + (d+\ell\cos\gamma)\omega_{\text{arm}}\,\hat{\jmath} - (d+\ell\cos\gamma)\omega_{\text{arm}}\,\hat{k}$

$$\vec{a}_E = -\omega_{\text{arm}}^2(d+\ell\cos\gamma)\,\hat{\imath} - \omega_{\text{arm}}^2\sin\gamma(d+\ell\cos\gamma)\,\hat{\jmath} - \frac{\omega_{\text{arm}}^2}{R}\left[d^2 + 2d\ell\cos\gamma + \left(\ell^2+R^2\right)\cos^2\gamma\right]\hat{k}$$

10.8 $\vec{v}_E = R\omega_{\text{arm}}\cos\gamma\,\hat{\imath} + (d+\ell\cos\gamma)\omega_{\text{arm}}\,\hat{\jmath} - (d+\ell\cos\gamma)\omega_{\text{arm}}\,\hat{k}$

$$\vec{a}_E = \left[R\alpha_{\text{arm}} - \omega_{\text{arm}}^2(d+\ell\cos\gamma)\right]\cos\gamma\,\hat{\imath} + (d+\ell\cos\gamma)\left(\alpha_{\text{arm}} - \omega_{\text{arm}}^2\sin\gamma\right)\hat{\jmath} - \frac{1}{R}\left[d\left(R\alpha_{\text{arm}} + d\omega_{\text{arm}}^2\right) + \ell\left(R\alpha_{\text{arm}} + 2d\omega_{\text{arm}}^2\right)\cos\gamma + \left(\ell^2+R^2\right)\omega_{\text{arm}}^2\cos^2\gamma\right]\hat{k}$$

10.10 $\vec{v}_B = \left(\dot{\ell}\cos\theta - \ell\dot{\theta}\sin\theta\right)\hat{\imath} + \ell\omega_1\cos\theta\,\hat{\jmath} + \left(\ell\dot{\theta}\cos\theta + \dot{\ell}\sin\theta\right)\hat{k}$

$$\vec{a}_B = \left[-\ell\left(\dot{\theta}^2 + \omega_1^2\right)\cos\theta - 2\dot{\ell}\dot{\theta}\sin\theta\right]\hat{\imath} + 2\omega_1\left(\dot{\ell}\cos\theta - \ell\dot{\theta}\sin\theta\right)\hat{\jmath} + \dot{\theta}\left(2\dot{\ell}\cos\theta - \ell\dot{\theta}\sin\theta\right)\hat{k}$$

10.12 $\vec{\omega}_{\text{disk}} = \omega_b\,\hat{\imath} + \omega_d\,\hat{k}$

$\vec{\alpha}_{\text{disk}} = \dot{\omega}_b\,\hat{\imath} - \omega_d\omega_b\,\hat{\jmath} + \dot{\omega}_d\,\hat{k}$

10.14 $\vec{\omega}_c = -\omega_0\dfrac{\cos\beta}{\sin\beta}\,\hat{\imath}$

$\vec{\alpha}_c = \dfrac{\cos\beta}{\sin\beta}\left(-\alpha_0\,\hat{\imath} + \omega_0^2\,\hat{k}\right)$

10.16 $\vec{v}_B = -L\omega_0\cos\beta\,\hat{\jmath} - L\omega_0\cos^2\beta\,\hat{k}$

$\vec{a}_B = -L\omega_0^2\cos^2\beta\,\hat{\imath} + L\alpha_0\cos\beta\,\hat{\jmath} - L\cos\beta\cot\beta\left(\omega_0^2 + \alpha_0\sin\beta\right)\hat{k}$

10.18 $\vec{a}_A = \left(231.3\,\hat{\jmath} + 107.9\,\hat{k}\right)\text{ft/s}^2$

$\vec{\alpha}_{AB} = \left(18.29\,\hat{\imath} + 15.08\,\hat{\jmath} + 34.90\,\hat{k}\right)\text{rad/s}^2$

10.20 $\vec{\omega}_{AB} = -\omega_s\,\hat{\jmath} - \dot{\beta}\,\hat{k}$

$\vec{\alpha}_{AB} = \dot{\beta}\omega_s\,\hat{\imath} - \alpha_s\,\hat{\jmath} - \ddot{\beta}\,\hat{k}$

$$\vec{a}_G = -\left[\frac{L}{2}\ddot{\beta}\sin\beta + \left(d + \frac{L}{2}\cos\beta\right)\omega_s^2 + \frac{L}{2}\dot{\beta}^2\cos\beta\right]\hat{\imath} + \frac{L}{2}\left(\dot{\beta}^2\sin\beta - \ddot{\beta}\cos\beta\right)\hat{\jmath} + \left[\left(d + \frac{L}{2}\cos\beta\right)\alpha_s - L\dot{\beta}\omega_s\sin\beta\right]\hat{k}$$

10.22 $\vec{\omega}_{AB} = \left(0.3139\,\hat{\imath} + 10.37\,\hat{\jmath} + 2.786\,\hat{k}\right)\text{rad/s}$

$\vec{\alpha}_{AB} = \left(-35.35\,\hat{\imath} + 135.2\,\hat{\jmath} + 161.9\,\hat{k}\right)\text{rad/s}^2$

10.24 $\vec{a}_A = \left(101.8\,\hat{\jmath} + 47.49\,\hat{k}\right)\,\text{m/s}^2$

10.26 $\vec{v}_A = \left(-0.7354\,\hat{\jmath} - 0.3429\,\hat{k}\right)\,\text{m/s}$ and $\vec{a}_A = \left(-12.49\,\hat{\jmath} - 5.825\,\hat{k}\right)\,\text{m/s}^2$

10.28 $\vec{\alpha}_{AB} = \left(-6.040\,\hat{\jmath} - 8.054\,\hat{k}\right)\,\text{rad/s}^2$

10.30 $\vec{a}_A = -124.2\,\hat{\imath}\,\text{m/s}^2$

10.32

$$\begin{aligned}\vec{\alpha}_{AB} = {}& -11.84\cos\theta\,\hat{\imath} + \frac{4.187}{Z^{3/2}}\Big[26.25\cos\theta + 0.7500\big(19.53\cos 2\theta \\ &- 5.400\cos 3\theta + 0.5625\cos 4\theta - 24.55\big)\Big]\,\hat{\jmath} \\ &- \frac{101.2}{Z^{3/2}}\Big[-7.438\cos\theta + 0.7500\big(-1.200 - 3.600\cos 2\theta + 0.7500\cos 3\theta\big)\Big]\,\hat{k}\,\text{rad/s}^2,\end{aligned}$$

where $Z = (7.438 + 3.600\cos\theta - 0.5625\cos 2\theta)\,\text{m}^2$

$$\begin{aligned}\vec{a}_A = {}& \frac{29.08}{Z^{3/2}}\Big[-31.37 + 25.92\cos\theta^2 + 1.688\cos 2\theta \\ &- 4.800\cos\theta\big(1.688\cos 2\theta - 6.312\big) - 22.63\sqrt{Z}\sin\theta \\ &+ 0.7500\big(0.5625\cos 4\theta + 2\sqrt{2}(0.7500\cos\theta - 2.400)\sqrt{Z}\sin 2\theta\big)\Big]\,\hat{\imath}\,\text{m/s}^2,\end{aligned}$$

where $Z = (7.438 + 3.600\cos\theta - 0.5625\cos 2\theta)\,\text{m}^2$

10.34 $\vec{v}_B = (v_t + h\omega_a)\,\hat{\imath} + (\ell + r_t)\,\omega_b\,\hat{\jmath} - (\ell + r_t)\,\omega_a\,\hat{k}$

10.36 $\vec{\omega}_{\text{bar}} = \pm\sqrt{\dfrac{24g\,(1+\sin\theta)}{L\sin\theta\,(5+3\sin\theta)}}\,\hat{\imath}$

10.38 $\omega_{10} = 4554\,\text{rad/s}$

10.40 $\frac{1}{3}L\ddot{\beta} + \left(\frac{1}{3}L\cos\beta + \frac{1}{2}d\right)\omega_s^2\sin\beta - \frac{1}{2}g\cos\beta = 0$

10.42

$$\begin{aligned}O_x &= -m\big(h + \tfrac{L}{2}\big)\omega_s^2, \\ O_y &= 0, \\ O_z &= mg, \\ M_{Ox} &= 0, \\ M_{Oy} &= -mg\big(h + \tfrac{L}{2}\big) + \tfrac{1}{2}mr^2\omega_d\omega_s, \\ M_{Oz} &= 0\end{aligned}$$

10.44 $v_{A2} = 6.294\,\text{m/s}$

10.46 $v_{A2} = 6.165\,\text{m/s}$

10.48

$$\begin{aligned}M_{Ax} &= -\frac{1}{2}mR^2\dot{\theta}\dot{\phi}\cos\theta, \\ M_{Ay} &= \frac{1}{4}mR^2\dot{\phi}^2\cos\theta\sin\theta + \frac{1}{2}mR^2\dot{\phi}\cos\theta\left(\dot{\psi} - \dot{\phi}\sin\theta\right), \\ M_{Az} &= -\frac{1}{2}mR^2\dot{\theta}\dot{\phi}\sin\theta - \frac{1}{2}mR^2\dot{\theta}\left(\dot{\psi} - \dot{\phi}\sin\theta\right)\end{aligned}$$

10.50

$$\begin{aligned}M_X &= 0, \\ A_Y &= \frac{m}{8L}R^2\omega_s^2\cos\theta\sin\theta, \\ A_Z &= 0, \\ B_Y &= \frac{m}{8L}R^2\omega_s^2\cos\theta\sin\theta, \\ B_Z &= 0,\end{aligned}$$

where XYZ is attached to the shaft.

10.52 $R_x = -0.5236t^2\,\text{N}$, $R_y = 0.021\,93\,\text{N}$, $R_z = 0.098\,10\,\text{N}$,
$M_x = 0.000\,092\,91\,\text{N·m}$, $M_y = 0.002219t^2\,\text{N·m}$, $M_z = 0.000\,068\,55\,\text{N·m}$

10.54 $\omega_s = \sqrt{\dfrac{3g}{L}}$

10.56 $N = \dfrac{8mg\,(1+\cos\beta) + mR\omega_0^2\left(4\cos\beta + 4\cos^2\beta - 16\sin\beta - 17\cos\beta\sin\beta\right)}{4\,(2+2\cos\beta-\sin\beta)}$

10.58 $(\omega_0)_{\text{min}} = \sqrt{\dfrac{5g}{7R}}$

10.60 $\vec{\alpha}_d = -\dfrac{h}{R}\omega_b^2\,\hat{\imath} + \dot{\omega}_b\,\hat{\jmath} - \dfrac{h}{R}\dot{\omega}_b\,\hat{k}$

10.62 $$\vec{a}_P = \left[h\dot{\omega}_b\cos\beta + \left(\frac{h^2+R^2}{R}\right)\omega_b^2\sin\beta\right]\hat{\imath} + \left[h\dot{\omega}_b\sin\beta - \left(\frac{h^2}{R}\right)\omega_b^2\cos\beta\right]\hat{\jmath} + \left[R\dot{\omega}_b\sin\beta - h\omega_b^2\,(1+2\cos\beta)\right]\hat{k}$$

10.64 $O_X = -mL\omega_0^2$, $O_Y = mg$,
$O_Z = -mL\dot{\omega}_0$, $M_X = \dfrac{1}{12}mL^2\dot{\omega}_0\cos\theta\sin\theta$,
$M_Y = mL^2\dot{\omega}_0\left(1 - \dfrac{\sin^2\theta}{12}\right)$, $M_Z = mgL - \dfrac{1}{12}mL^2\omega_0^2\cos\theta\sin\theta$

10.66 $O_X = -mL\omega_0^2$, $O_Y = mg$,
$O_Z = -mL\dot{\omega}_0$, $M_X = \dfrac{3}{16}mL^2\dot{\omega}_0\cos\theta\sin\theta$,
$M_Y = \dfrac{1}{16}mL^2\dot{\omega}_0\left(17 - 3\sin^2\theta\right)$, $M_Z = mgL - \dfrac{1}{16}mL^2\omega_0^2\cos\theta\sin\theta$

10.68 $\dot{\phi} = \dfrac{675 \times 15^{1/3}\csc^2\theta}{4mL^2\,(1+\sin\theta)}$

10.70 $$\vec{\alpha}_{AB} = -\frac{2dhR^2\omega_d^2}{\left(d^2+h^2\right)^2}\,\hat{\imath} - \frac{hR^2\left[d^4 + h^2\,(\ell-R)^2 + d^2(h+R-\ell)(h-R+\ell)\right]\omega_d^2}{\left(d^2+h^2\right)^2(\ell-R)^3}\,\hat{\jmath} - \frac{dR^2\left[d^4 + d^2h^2 + 2h^2\,(\ell-R)^2\right]\omega_d^2}{\left(d^2+h^2\right)^2(\ell-R)^3}\,\hat{k},$$
$$= \left(-26.32\,\hat{\imath} - 0.9870\,\hat{\jmath} - 17.77\,\hat{k}\right)\text{rad/s}^2,$$
where $\ell = \sqrt{L_{AB}^2 - d^2 - h^2} + R$,

10.72 $\vec{a}_A = -\dfrac{R\left[d^2R + \ell\,(\ell-R)^2\right]\omega_d^2}{(\ell-R)^3}\,\hat{\imath} = -124.2\,\hat{\imath}\,\text{m/s}^2$, where $\ell = \sqrt{L_{AB}^2 - d^2 - h^2} + R$,

10.74

$$\vec{a}_A = -\frac{R\omega_d^2}{4(\ell - R\sin\theta)^3}\Big[2d^2R - 6R\ell^2 - d\left(R^2 - 4\ell^2\right)\cos\theta + 2R\left(-d^2 + \ell^2\right)\cos 2\theta$$

$$+ dR^2\cos 3\theta + 5R^2\ell\sin\theta + 4\ell^3\sin\theta - 4dR\ell\sin 2\theta + R^2\ell\sin 3\theta\Big]\,\hat{\imath},$$

$$= -\frac{20.56}{(2.750 - 0.7500\sin\theta)^3}\Big[-31.87 + 35.62\cos\theta + 9.184\cos 2\theta + 0.6750\cos 3\theta$$

$$+ 90.92\sin\theta - 9.900\sin 2\theta + 1.547\sin 3\theta\Big]\ \text{rad/s}^2,$$

$$\text{where } \ell = \sqrt{L_{AB}^2 - d^2 - h^2} + R,$$

$$\vec{\alpha}_{AB} = \frac{hR\omega_d^2\left[\left(4\left(d^2 + h^2\right) + 5R^2\right)\cos\theta - R\left(8d + R\cos 3\theta\right)\right]}{4\left[d^2 + h^2 + R\cos\theta\left(R\cos\theta - 2d\right)\right]^2}\,\hat{\imath}$$

$$+ \frac{hR\omega_d^2}{\left[d^2 + h^2 + R\cos\theta\left(R\cos\theta - 2d\right)\right]^2\left(R\sin\theta - \ell\right)^3}\Big\{R^3\ell\cos^4\theta\left(2R\sin\theta - \ell\right)$$

$$- dR^2\cos^3\theta\left[-3\ell^2 + R\sin\theta\left(6\ell + R\sin\theta\right)\right]$$

$$- R\cos^2\theta\Big[\left(3d^2 + h^2\right)\ell^2 + R\sin\theta\big[-2\left(3d^2 + h^2\right)\ell$$

$$+ R\sin\theta\left(\ell^2 - 3d^2 + R\sin\theta\left(R\sin\theta - 2\ell\right)\right)\big]\Big]$$

$$+ d\cos\theta\Big[\left(d^2 + h^2\right)\ell^2 + R\sin\theta\big[-2\left(d^2 + h^2\right)\ell$$

$$+ R\sin\theta\left(-3d^2 - h^2 + 2R\sin\theta\left(R\sin\theta - 2\ell\right)\right)\big]\Big]$$

$$+ R\sin\theta\Big[\sin\theta\big(d^4 + h^2\ell^2 + d^2\left(h^2 - \ell^2\right)$$

$$+ \left(d^2 - h^2\right)R\sin\theta\left(2\ell - R\sin\theta\right)\big) + dR\ell^2\sin 2\theta\Big]\Big\}\,\hat{\jmath}$$

$$+ \frac{R\omega_d^2\left(R\cos\theta - d\right)}{\left[d^2 + h^2 + R\cos\theta\left(R\cos\theta - 2d\right)\right]^2\left(R\sin\theta - \ell\right)^3}\Big\{2h^2R^2\sin^3\theta\left(2\ell - R\sin\theta\right)$$

$$+ \ell^2\cos\theta\left(R\cos\theta - d\right)\left[d^2 + h^2 + R\cos\theta\left(R\cos\theta - 2d\right)\right]$$

$$+ 2R\ell\cos\theta\left(d - R\cos\theta\right)\left(d^2 + h^2 + R\cos\theta\left(R\cos\theta - 2d\right)\right)\sin\theta$$

$$+ R\Big[-d^2\left(d^2 + h^2\right) - 2h^2\ell^2$$

$$+ dR\cos\theta\left(3d^2 + h^2 + R\cos\theta\left(R\cos\theta - 3d\right)\right)\Big]\sin^2\theta\Big\}\,\hat{k},$$

$$= \frac{-133.2 + 218.6\cos\theta - 10.41\cos 3\theta}{\left[2.250 + (-1.800 + 0.5625\cos\theta)\cos\theta\right]^2}\,\hat{\imath}$$

$$+ \frac{(-2.750 + 0.7500\sin\theta)^{-3}}{\left[2.250 + (-1.800 + 0.5625\cos\theta)\cos\theta\right]^2}\Big[-1229 - 1142\cos 2\theta + 149.8\cos 3\theta$$

$$- 18.22\cos 4\theta + 5.270\cos 5\theta - 0.5489\cos 6\theta$$

$$+ \cos\theta\left(2490 - 1340\sin\theta\right) + 434.1\sin\theta + 289.8\sin 3\theta - 25.76\sin 4\theta\Big]\,\hat{\jmath}$$

$$+ \frac{(-2.750 + 0.7500\sin\theta)^{-3}}{\left[2.250 + (-1.800 + 0.5625\cos\theta)\cos\theta\right]^2}\Big[-1889 - 3302\cos 2\theta$$

$$+ 1170\cos 3\theta - 199.7\cos 4\theta + 19.03\cos 5\theta - 0.7319\cos 6\theta$$

$$+ \cos\theta\left(4329 - 1880\sin\theta\right) + 278.2\sin\theta + 815.8\sin 3\theta$$

$$- 277.5\sin 4\theta + 42.94\sin 5\theta - 3.355\sin 6\theta\Big]\,\hat{k}\ \text{rad/s}^2$$