Chapter **12** (Benson)

E01 $\vec{l}_1 = 18\,\hat{k}$ kg·m²/s; $\vec{l}_2 = -9.70\,\hat{k}$ kg·m²/s; $\vec{l}_3 = -23.5\,\hat{k}$ kg·m²/s; $\vec{l}_4 = 15\,\hat{k}$ kg·m²/s; $\vec{L} = -0.2\,\hat{k}$ kg·m²/s .

E04 $K = I\omega^2/2$, $L = I\omega$, so $K = L^2/(2I)$.

E05 $\sum l_x = 0$, $\sum l_y = 0$, $\sum l_z = 2mR^2\omega$.

E08 (a) $mv^2/r = ke^2/r^2$, so $v = (ke^2/mr)^{1/2}$. Substitute v into $mrv = nh/2\pi$ to find $r = (nh/2\pi)^2/kme^2$.

E09 (a) $\tau = (m_2 - m_1)gR = 1.57$ N·m; (b) $L = (m_1 + m_2)vR + I(v/R) = 0.80v$; (c) $\tau = dL/dt$: $1.57 = 0.8a$, thus $a = 1.96\,\mathrm{m/s^2}$.

E10 $L = mvR + I\omega = (m + M/2)\,vR$, $\tau = mgR$. From $\tau = dL/dt$ we get $a = mg/(m + M/2) = 4.9\,\mathrm{m/s^2}$.

E11 $x(t) = A\,t^3$, $y(t) = b\,t^2 - Ct$. $\vec{v} = 3At^2\,\hat{i} + (2Bt - C)\,\hat{j}$; $\vec{a} = 6At\,\hat{i} + 2B\,\hat{j}$. (a) $\vec{L} = \vec{r} \times \vec{p} = MAt^3(2C - Bt)\,\hat{k}$; (b) $\vec{F} = m\vec{a} = M(6At\,\hat{i} + 2B\,\hat{j})$.

E17 (a) $L_i = mRv = 900$ kg·m²/s; $L_f = (mR^2 + MR^2/2)\,\omega = 990\,\omega$, thus $\omega = 0.909$ rad/s; (b) $K_i = mv^2/2 = 750$ J, $K_f = (mR^2 + MR^2/2)\,\omega^2/2 = 409$ J. Thus $\Delta K = -341$ J .

E23 $L_i = (MR^2/2)\,\omega_i$, $L_f = (mR_b^2 + MR^2/2)\,\omega_f$, so $\omega_f = M\omega_i/(M + m) = 4.16$ rad/s .

E25 $mV_i^2/r_i = 2Mg$, $mV_f^2/r_f = Mg$, $r_f V_i^2 = 2\,r_i V_f^2$ ..① $L_i = mr_iV_i$, $L_f = mr_fV_f$, $r_iV_i = r_fV_f$ ..②. Solve ① and ② to find $r_f^3 = 2r_i^3$ or $r_f = 1.26\,r_i$.

E40 $m = 60$ kg, $d = 50$ cm & $L = 3$ m: For left support, $mg(L - d) = F_l\,d$, so $F_l = 2940$ N (down). For right support, $mgL = F_r\,d$, so $F_r = 3530$ N (up) .

E43 $L = 1.6$ m, $F_l = 300$ N & $F_r = 350$ N: $F_l\,x = F_r\,(L - x)$, thus $x = 0.862$ m from feet .

P01 $m = 0.5$ kg, $M = 1$ kg & $u = 4$ m/s. (a) $\sum P$: $mu = (2M + m)v_{cm}$, $v_{cm} = 0.8$ m/s; (b) Position of CM after collision: $d = MR/(M + m) = 0.8$ m. $\sum L$: $mud = (M + m)d^2\omega + M(R - d)^2\omega$, thus $\omega = 2/3$ rad/s .

P02 Let u_1, u_2 be the approaching, bouncing speeds of the ball, V be the recoil speed of CM of the bat. $\sum P$: $mu_1 = -mu_2 + MV$; $\sum L$: $m(d + L/2)u_1 = -m(d + L/2)u_2 + I_p\,\omega$, with $V = (L/2)\,\omega$. So $d = L/2$. (Teacher: Jyh-Shinn Yang, 89.01.0)

P03 $L_0 = mr_1v_1 = mrv = L$. (a) $F_r = mv^2/r = L_0^2/mr^3$; (b) $W = \int F_r dr = (L_0^2/2m)(1/r_2^2 - 1/r_1^2)$; (c) $K = L_0^2/2mr^2$ thus $\Delta K = (L_0^2/2m)(1/r_2^2 - 1/r_1^2)$; (d) Yes .

P05 (a) $f_k = Ma_{cm}$, so $a_{cm} = g\mu_k$; $-f_kR = I_c\alpha$, so $\alpha = -2\mu_k g/R$; (b) $v_{cm} = \omega R$ occurs as $a_{cm}t = (\omega_0 + \alpha\,t)R$, thus $t = \omega_0 R/3g\mu_k$; (c) $x = a_{cm}t^2/2 = (\omega_0 R)^2/18g\mu_k$.

P06 (a) $L_i = L_{spin} = I_{cm}\,\omega_0 = MR^2\omega_0/2$; (b) $\tau = 0$; (c) $L_f = L_{spin} + L_{orb} = I_{cm}\omega + MRv_{cm}$; (d) When pure rolling starts $\omega = v_{cm}/R$, thus $L_f = 3MRv_{cm}/2$. Set $L_f = L_i$ to find

$v_{cm} = \omega_0 R/3$.

P07 $f = Ma_{cm} = \mu_k Mg$, $a_{cm} = g\mu_k$; $fR = I\alpha = (2MR^2/5)\,\alpha$, thus $\alpha = 5g\mu_k/(2R)$. For pure rolling $v_{cm} = \omega\, R$, thus $v_0 - a_{cm}\, t = \alpha\, tR$ or $v_0 = (a_{cm} + \alpha\, R)\, t = 7g\mu_k\, t/2$ and $t = 2v_0/(7g\mu_k)$. (a) $v_{cm} = 5v_0/7$; (b) $v^2 = v_0^2 - 2a_{cm}\Delta x$; $\Delta x = 24v_0^2/(98g\mu_k)$.

P10 $T - f_s = Ma_{cm}$, $f_s R - Tr = (MR^2/2)\alpha$. For no slipping $\alpha = a_{cm}/R$. So $T = 3Rf_s/(R + 2r) \leq 3\mu_s MgR/(R + 2r)$.

P12 $\sum F$: $F - f = Ma_{cm}$; $\sum \tau$: $fR = I\alpha = (MR^2/2)(a_{cm}/R)$. Thus $f = Ma_{cm}/2$ and then $F = 3Ma_{cm}/2 = 3f \leq 3\mu Mg$. Thus $\mu \leq F/(3Mg)$.

P15 (a) $d_1 = L/2$; (b) $2mx_{cm} = 2mL = m(d_2 + L/2) + m(d_2 + L)$, so $d_2 = L/4$; (c) $(d_3 + L/2) + (d_3 + d_2 + L/2) + (d_3 + d_2 + L) = 3L$, so $d_3 = L/6$.

P16 (a) When weights (W) passes through lower corner: $\tan\theta = b/h$; (b) $mg\sin\theta = \mu_s mg\cos\theta$, $\tan\theta = \mu_s$; (c) Slide; (d) Topple .

P17 (a) About the right corner $Fy = Wb/2$; so $y = Wb/(2F) = 0.613\,\text{m}$; (b) Torque about the CG: $fh/2 - Nx = 0$. Also $f = F$ & $N = W$. Thus, $x = Fh/(2W) = 0.224\,\text{m}$ from the central line . (Teacher: Jyh-Shinn Yang, 89.01.03)

P19 W_2, W_1: masses of ladder, person. $[W_2(1.5) + W_1(1)]\cos\theta = N_2(3\sin\theta)$; $N_2 = 65g/(3g\tan\theta) = 77.3\,\text{N}$. $N_1 = W_1 + W_2 = 588\,\text{N}$, and $f_1 = N_2 = 77.3\,\text{N}$.

P20 $\mu_s = 0.6$. $N_1 = W_1 + W_2 = 13W$, $f_1 = \mu_s(13W) = N_2$. $(WL/2 + 12Wd)\cos\theta = N_2 L\sin\theta = 13WL\sin\theta$. Thus, $d = L(13\mu_s\tan\theta - 0.5)/12 = 0.733L$.