9-50 MOMENTUM IS CONSERVED

$P_i = mv_i$ $\qquad$ $P_f = (m+M)v_f$

SO ~~$v_f$~~ since $mv_i = (m+M)v_f$

$$v_f = \frac{mv_i}{(m+M)}$$

NOW, AS THE PENDULUM SWINGS, MECHANICAL ENERGY MUST BE CONSERVED

$E_i = \frac{1}{2}(m+M)v_f^2$ $\qquad$ $E_f = (m+M)gh + K.E._f$

BUT $h = 2\ell$

AND $K.E._f$ CAN BE AS SMALL AS ZERO.

SO

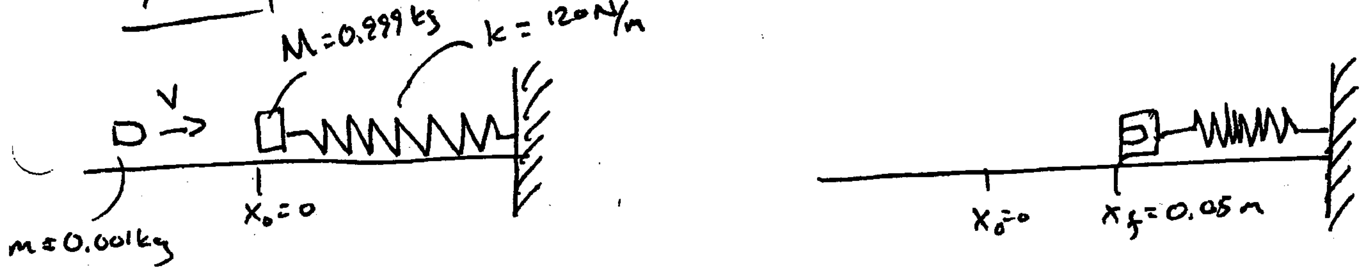
$$\frac{1}{2}(m+M)v_f^2 = (m+M)g2\ell$$

$$\frac{1}{2}\left(\frac{mV_i}{(m+M)}\right)^2 = g2\ell \qquad \text{SOLVE FOR } V_i$$

$$V_i^2 = 4\left(\frac{m+M}{m}\right)^2 g\ell$$

$$\boxed{V_i = 2\left(\frac{m+M}{m}\right)\sqrt{g\ell}}$$

9-51 / THESE JUST KEEP GETTING HARDER!




(a)

DURING THE COLLISION, MOMENTUM IS CONSERVED.

TOTAL MASS, VELOCITY.

$$P_i = m_b v_b = P_f = m_T v_T$$

$$v_T = \frac{m_b v_b}{m_T}$$

DURING SPRING COMPRESSION WE MUST ACCOUNT FOR ENERGY CONVERSION

$$E_i = \frac{1}{2} m_T v_T^2 \qquad E_f = \frac{1}{2} k x^2$$

AND

WORK DONE BY FRICTION

$$E_f - E_i = W_\mu$$

SO $$\frac{1}{2}kx^2 - \frac{1}{2}m_T v_T^2 = -\mu m_T g x$$

$F_\mu = \mu N = \mu m_T g$

BUT FROM ABOVE $$v_T = \frac{m_b v_b}{m_T}$$

SO WE HAVE

$$\frac{1}{2}kx^2 - \frac{1}{2}m_T\left(\frac{m_b v_b}{m_T}\right)^2 = -\mu m_T g x$$

NOW WE CAN SOLVE FOR $v_b$

$$v_b^2 = \frac{(2\mu m_T x g + kx^2)m_T}{m_b^2}$$

$$v_b = \left(\frac{m_T}{m_b^2}(2\mu m_T x g + kx^2)\right)^{1/2}$$

$$\boxed{v_b = 894 \text{ m/s}}$$

9-51 (CONTINUED)

(b) BECAUSE $P_i = P_f \rightarrow m_b V_b = m_T V_T$

$KE_b \neq KE_T$ THEN $\Delta K.E. = K.E._T - K.E._b$

NECESSARILY.

$$\Delta K.E. = \frac{1}{2} m_T V_T^2 - \frac{1}{2} m_b V_b^2$$

BUT $V_T = \dfrac{m_b V_b}{m_T}$ SO

$$\Delta KE = \frac{1}{2} m_T \left(\frac{m_b V_b}{m_T}\right)^2 - \frac{1}{2} m_b V_b^2$$

PLUG IN THE #'S TO GET

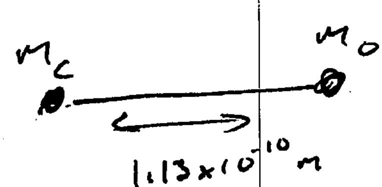
$$\Delta K.E. = -399 J$$

FRACTION LOST IS

$$\frac{\Delta K.E.}{KE_b} = \frac{399 J}{\frac{1}{2} m_b V_b^2} = \cancel{36}\ 0.999$$

SO 99.9% OF THE ENERGY IS LOST!

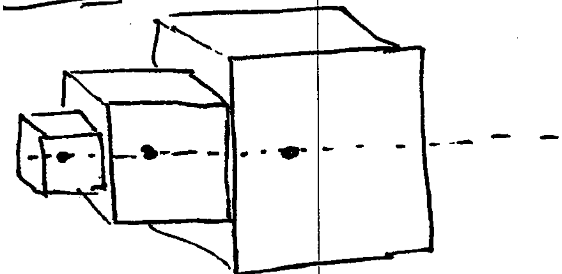
9-63




$$x_{cm} = \frac{(12u)(0m) + (16u)(1.13\times10^{-10} m)}{(12u + 16u)}$$

$$\boxed{x_{cm} = 6.5\times10^{-11} m \text{ FROM CARBON ATOM}}$$

9-64



$$x_{cm} = \frac{x_1 m_1 + x_2 m_2 + x_3 m_3}{m_1 + m_2 + m_3}$$

$x_1 = \frac{l_0}{2}$ $x_2 = \frac{2l_0}{2} + l_0 = 2l_0$

$x_3 = 3l_0 + \frac{3l_0}{2} = \frac{9l_0}{2}$

$m_1 = m$
$m_2 = 8m_0$
$m_3 = 27m_0$

$$x_{cm} = \frac{(\frac{l_0}{2})(m) + (2l_0)(8m) + (\frac{9l_0}{2})(27m)}{36m}$$

$$\boxed{x_{cm} = 3.8\, l_0}$$

10-7 (A) SECOND HAND GOES $-2\pi$ rad IN 60s

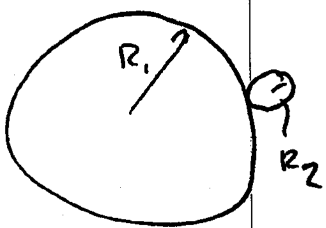
SO $\omega = \frac{-2\pi}{60s} = -.10 \frac{rad}{sec}$

(B) $\omega = \frac{-2\pi}{3600s} = -1.7\times10^{-3}$ rad/s

(C) $\omega = \frac{-2\pi}{12 hrs} = \frac{-2\pi}{43,200s} = -1.45\times10^{-4}$ rad/s

(d) $\alpha = 0$ FOR ALL

10-14




THE LINEAR VELOCITY $V$ MUST BE THE SAME AT THE CONTACT.

SO

$$V = \omega r$$

$$\omega_1 R_1 = \omega_2 R_2 \longrightarrow \boxed{\frac{\omega_1}{\omega_2} = \frac{R_2}{R_1}}$$

10-19

(A) WE DON'T KNOW HOW LONG IT TOOK, BUT WE CAN USE

$$\omega^2 - \omega_0^2 = 2\alpha(\theta - \theta_0)$$

$$\omega = 0, \quad \omega_0 = \frac{850 (2\pi) \text{ rad/m}}{60 \text{ s/m}} = 89 \text{ rad/s}$$

$$\theta_0 = 0, \quad \theta = 1350 \cdot (2\pi \text{ rad}) = 8482.3 \text{ rad}$$

$$-\omega_0^2 = 2\alpha(\theta) \longrightarrow \boxed{\alpha = \frac{-\omega_0^2}{2\theta} = -0.47 \text{ rad/s}^2}$$

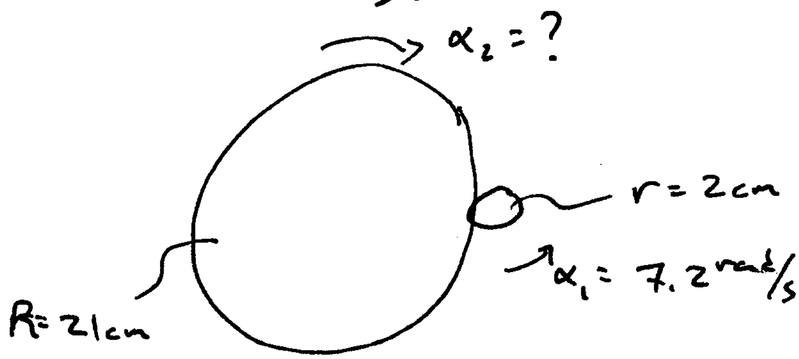
(b) NOW THAT WE HAVE $\alpha = -0.47 \text{ rad/s}^2$ WE CAN USE

$$\omega = \omega_0 + \alpha t$$

$$(0 \text{ rad/s}) = (89 \text{ rad/s}) + (-0.47 \text{ rad/s}^2)\, t$$

$$t = \frac{(89 \text{ rad/s})}{(-0.47 \text{ rad/s}^2)} \qquad \boxed{t = 189 \text{ s}}$$

10-21




A) SINCE THE EDGES DON'T SLIP WE KNOW THEY MUST HAVE THE SAME TANGENTIAL VELOCITY AT ALL TIMES, AND HENCE, THE SAME TANGENTIAL ACCELERATION.

SO WE CAN WRITE

$$a_1 = a_2 \rightarrow \alpha_2 R = \alpha_1 r$$

$$\alpha_2 = \alpha_1\left(\frac{r}{R}\right) = \left(7.2\ \frac{rad}{s}\right)\left(\frac{2cm}{21cm}\right)$$

$$\boxed{\alpha_2 = 0.69\ \frac{rad}{s^2}}$$

NOTE: $\alpha_2$ (AS DRAWN) IS CLOCKWISE IF $\alpha_1$ IS COUNTERCLOCKWISE!

B) WE USE

$$\omega_f = \omega_0 + \alpha t$$

$\omega_0 = 0$

$\omega_f = 65\ rpm\left(\frac{2\pi\ rad}{rotation}\right)\left(\frac{1\ min}{60\ sec}\right)$

$= 6.8\ rad/s$

$$(6.8\ rad/s) = \left(0.69\ \frac{rad}{s^2}\right)t$$

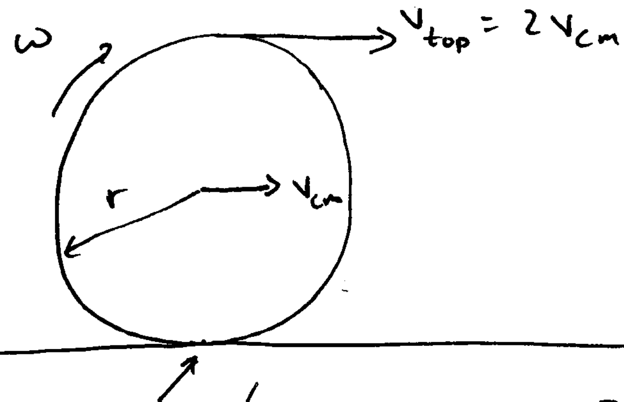
$$\boxed{t = 9.9\ s}$$

## 10-83

THE SPOOL ROLLS WITHOUT SLIPPING

SO $V_{cm} = r\omega$.

VELOCITY OF CENTER OF MASS




(INSTANT IN TIME.)

THE TOP MUST MOVE WITH THE ROPE, WHICH MEANS THAT THE CENTER OF MASS MOVES HALF AS FAST AS THE ROPE.

SO IF A LENGTH L OF ROPE IS PULLED OUT, THE SPOOL WILL HAVE ROLLED A DISTANCE OF $\boxed{L/2}$