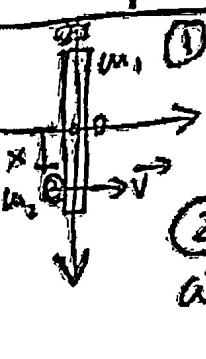

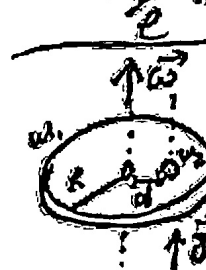



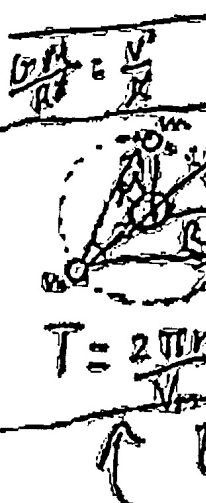
$m_1 = 9 \text{ kg}$ $m_2 = 1.5 \text{ kg}$ $\omega_0 = 2 \text{ rad/s}$
 Conservation of angular momentum
 $L_0 = I \omega_0 = \frac{m_1 r^2}{2} \omega_0 = L_1 = \frac{m_1 r^2}{2} \omega + m_2 r^2 \omega$
 $\frac{m_1 \omega_0}{2} = \omega \left(\frac{m_1}{2} + m_2 \right)$ $\omega = \frac{m_1 \omega_0}{m_1 + 2m_2} = \frac{9}{9+3} \text{ rad/s} = 4.5 \text{ rad/s}$


 ① $m_2 v = (m_1 + m_2) v_{cm}$ $v_{cm} = \frac{m_2}{m_1 + m_2} v$ $r_{cm} = \frac{x m_2}{m_1 + m_2}$
 $(x - r_{cm}) m_2 v = I \omega = \left(\frac{m_1 l^2}{12} + r_{cm}^2 m_1 + m_2 (x - r_{cm})^2 \right) \omega$ $\omega = \frac{(x - r_{cm}) m_2 v}{I}$
 ② $m_1 = m_2 = m$ $x = \frac{l}{2}$ $r_{cm} = \frac{l}{4}$ $v_{cm} = \frac{v}{2}$
 $\omega = \frac{r_{cm} v}{\frac{l^2}{12} + \frac{l^2}{8}}$ $J = \Delta p = m \omega r - m v$


 $J_x = \Delta p_x = -m_2 v$
 $I \omega = I' \omega'$ $\frac{m_1 l^2}{12} \omega = \left(\frac{m_1 l^2}{12} + \frac{m_2 l^2}{4} \right) \omega'$ $\omega' = \frac{m_1 \omega}{m_1 + 3m_2}$
 $J_y = \Delta p_y = m_2 \omega' \frac{l}{2}$ $J = \sqrt{J_x^2 + J_y^2}$ $\theta = \arcsin \frac{J_y}{J}$


 $L \omega = I \omega'$ $\frac{1}{2} m_1 R^2 \omega = \left(\frac{1}{2} m_1 R^2 + m_2 d^2 \right) \omega'$ $\omega' = \frac{m_1 R^2 \omega}{m_1 R^2 + 2m_2 d^2}$
 $J_y = m_2 \sqrt{g h}$ Impulse angular = $J \omega$


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$\frac{GM}{R^2} = \frac{v^2}{R}$ $T = \frac{2\pi R}{v}$ $T^2 = \frac{4\pi^2 R^3}{v^2} = \frac{4\pi^2}{GM} R^3$

 $P = m v_{cm} = 0$ $L = 3 R m v_{cm}$
 $\frac{mv^2}{R} = \frac{GMm}{R^2} + \frac{2GMm}{(2R \sin \theta)^2}$ $\frac{v^2}{R} = \frac{GM}{R^2} + \frac{2GM}{3R^2}$ $v = \sqrt{\frac{GM}{R} \left(1 + \frac{2}{3} \right)}$
 $T = \frac{2\pi R}{v}$
 $\frac{1}{a} = \frac{1}{M} + \frac{1}{m} = \frac{m+M}{Mm}$ $\mu = \frac{Mm}{m+M}$ $E_p = -3 \frac{GMm}{R}$ $E_k = \frac{1}{2} \frac{GMm}{R}$