

$$\textcircled{1} \textcircled{a} \quad p_1 = M_1 v_1 = 1.50 \times 10^4 \text{ kg-m/s} \quad p_2 = M_2 v_2 = 1.44 \times 10^4 \text{ kg-m/s}$$

let  $x$  be in easterly direction,  $y$  in northerly direction

$$\Rightarrow p_{1x} = p_1 \text{ and } p_{1y} = 0, \quad p_{2x} = -p_2 \cos \theta, \quad p_{2y} = p_2 \sin \theta$$

$$\Rightarrow P_x = p_{1x} + p_{2x} = p_1 - p_2 \cos \theta, \quad P_y = p_{1y} + p_{2y} = p_2 \sin \theta$$

$$\theta = 36.9^\circ \rightarrow P_x = 3.48 \times 10^3 \text{ kg-m/s} \quad P_y = 8.65 \times 10^3 \text{ kg-m/s}$$

$$\textcircled{1} \textcircled{b} \quad \text{Momentum conserv.} \Rightarrow \vec{P}_F = \vec{P} \Rightarrow (M_1 + M_2) V_F = P$$

$$Now \quad P = (P_x^2 + P_y^2)^{1/2} = 9.322 \times 10^3 \text{ kg-m/s}$$

$$M_1 + M_2 = 3300 \text{ kg} \Rightarrow V_F = P/(M_1 + M_2) = 2.82 \text{ m/s}$$

$$\tan \theta_F = P_y / P_x = 2.481 \Rightarrow \theta_F = 68^\circ \text{ N of E}$$

$$\textcircled{1} \textcircled{c} \quad K_{\text{init}} = \frac{1}{2} M_1 v_1^2 + \frac{1}{2} M_2 v_2^2 = 132.6 \text{ kJ}$$

$$K_{\text{final}} = \frac{1}{2} (M_1 + M_2) V_F^2 = 13.2 \text{ kJ} \Rightarrow K_{\text{lost}} = K_{\text{init}} - K_{\text{final}} = 119 \text{ kJ}$$

$$\textcircled{2} \textcircled{a} \quad \text{Period of motion} \rightarrow T = 2\pi/\omega = 1.047 \text{ s}$$

$$4 \text{ revs} \rightarrow \Delta t = 4T = 4.19 \text{ s}$$

$$\textcircled{2} \textcircled{b} \quad \text{Initially, } L_0 = I\omega_0 = 0.450 \text{ kg-m}^2/\text{s}^2$$

$$\text{After, } L = I'\omega \text{ with } I' = I_0 + ma^2 = 8.22 \times 10^{-2} \text{ kg-m}^2$$

$$\text{Ang. mom. conserv} \Rightarrow L = L_0$$

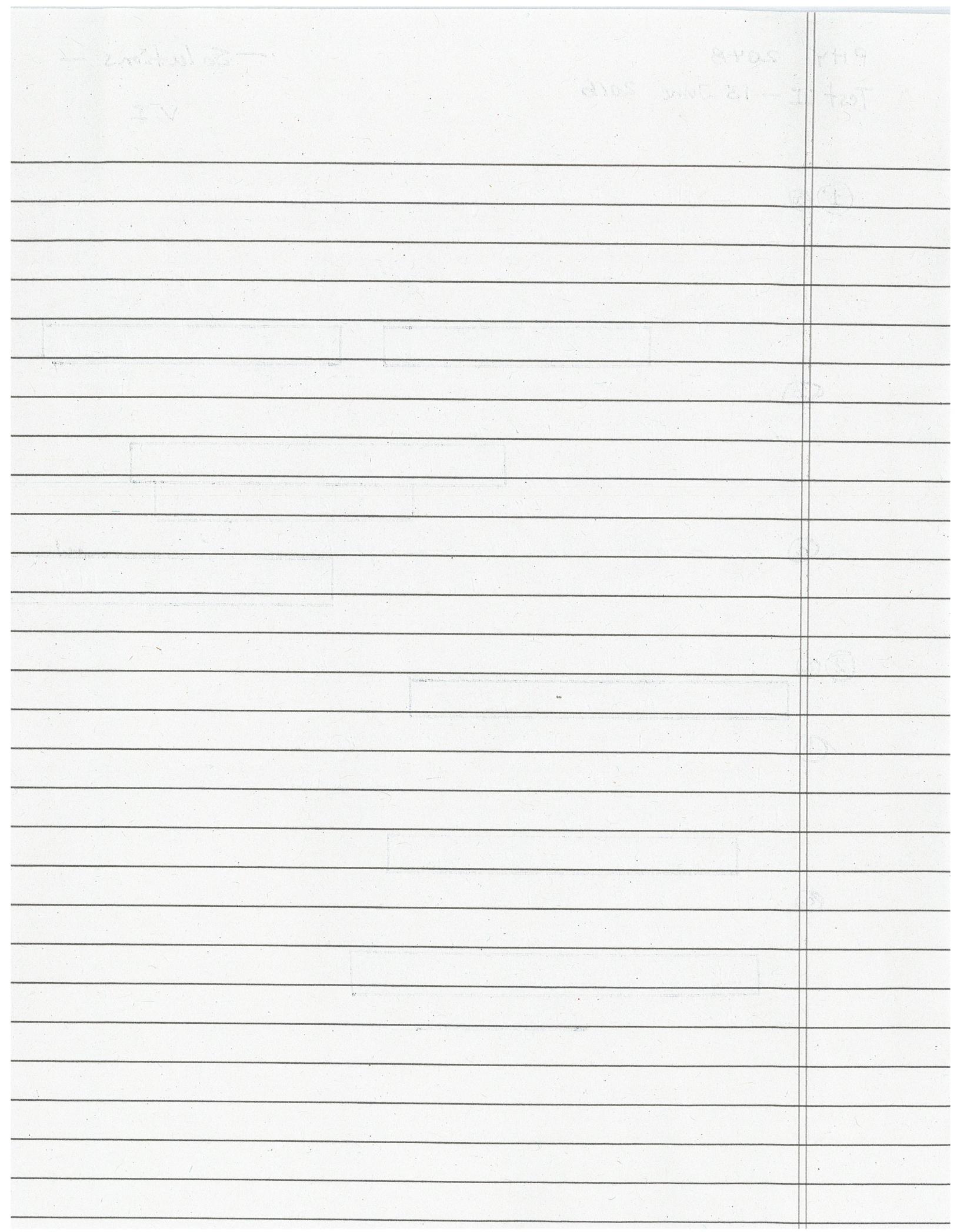
$$\Rightarrow \omega = L_0 / I' = 5.47 \text{ rad/s}$$

$$\textcircled{2} \textcircled{c} \quad K_{\text{init}} = \frac{1}{2} I\omega_0^2 = 1.35 \text{ J}$$

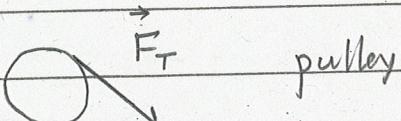
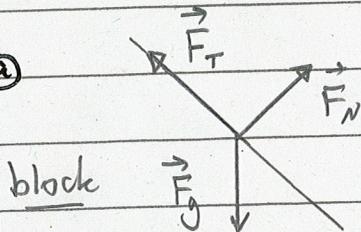
$$K_{\text{final}} = \frac{1}{2} I'\omega^2 = 1.232 \text{ J}$$

$$\rightarrow \Delta K = K_{\text{final}} - K_{\text{init}} = -0.12 \text{ J}$$

$\Delta K < 0 \Rightarrow \underline{\text{energy lost}}$



(3) a)



b) Block  $\rightarrow Ma = F_{\text{net}} = Mgs \sin \theta - F_T$

Pulley  $\rightarrow I\alpha = \tau_{\text{net}} = F_T R$

no slipping  $\rightarrow \alpha = a/R \Rightarrow Ia = F_T R^2 \Rightarrow F_T = Ia/R^2$

Substitute into 1<sup>st</sup> eqn  $\Rightarrow Ma = Mgs \sin \theta - Ia/R^2$

$$\Rightarrow a = Mgs \sin \theta / (M + I/R^2) = 4.78 \text{ m/s}^2$$

c) Constant accel  $\Rightarrow 2ad = v^2 \Rightarrow v = \sqrt{2ad} = 3.786 \text{ m/s}$

no slipping  $\Rightarrow \omega = v/R = 15.15 \text{ rad/s}$

$$\Rightarrow K_{\text{rot}} = \frac{1}{2} I \omega^2 = 6.88 \text{ J}$$

4) a)  $v_p = 3.60 \times 10^6 \text{ m/s} \Rightarrow p_p = 6.012 \times 10^{-21} \text{ kg-m/s}$

and  $K_p = \frac{1}{2} m_p v_p^2 = 1.082 \times 10^{-14} \text{ J}$

$$v_a = -2.40 \times 10^6 \text{ m/s} \Rightarrow p_a = -1.603 \times 10^{-20} \text{ kg-m/s}$$

and  $K_a = \frac{1}{2} m_a v_a^2 = 1.923 \times 10^{-14} \text{ J}$

$$\Rightarrow P = p_p + p_a = -1.00 \times 10^{-20} \text{ kg-m/s} \quad K_{\text{tot}} = K_1 + K_2 = 3.01 \times 10^{-14} \text{ J}$$

b) Momentum conserv  $\Rightarrow m_p v_p' + m_a v_a' = P$

Relative velocity  $\Rightarrow v_p' - v_a' = -(v_p - v_a) = -6.00 \times 10^6 \text{ m/s}$

Multiply 2<sup>nd</sup> equ. by  $m_a$  and add eqs

$$\rightarrow (m_a + m_p) v_p' = P - m_a (-6.00 \times 10^6 \text{ m/s}) = -5.01 \times 10^{-20} \text{ kg-m/s}$$

$$\Rightarrow v_p' = -6.00 \times 10^6 \text{ m/s} \rightarrow v_a' = 0$$

c) Before collision  $\rightarrow v_{cm} = (m_p v_p + m_a v_a) / (m_p + m_a) = -1.2 \times 10^6 \text{ m/s}$

After collision  $\rightarrow v_{cm} = (m_p v_p' + m_a v_a') / (m_p + m_a) = -1.2 \times 10^6 \text{ m/s}$

→ agree as expected

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