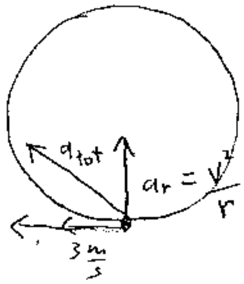
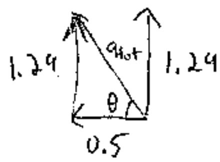


$a_r = \frac{v^2}{r} = \frac{9}{7} = 1.29\ \frac{m}{s^2} = a_r$

$a_t = 0.500\ \frac{m}{s^2}$



$|\vec{a}_{tot}| = 1.38\ \frac{m}{s^2}$

$\tan\theta = \frac{1.29}{0.5} \Rightarrow \theta = 68.8°$ above $-x$ axis.

$60\ \frac{mi}{hr}\ \frac{1\ hr}{3600\ s}\ \frac{1\ km}{0.6214\ mi}\ \frac{10^3\ m}{1\ km} = 26.8\ \frac{m}{s}$

$15\ in\ \frac{2.54\ cm}{1\ in}\ \frac{1\ m}{100\ cm} = 0.381\ m \Rightarrow r = 0.191\ m$

$V = \omega r \qquad \omega = \frac{V}{r} = \frac{26.8}{0.191} = 140\ \frac{rad}{s}$

$140\ \frac{rad}{s}\ \frac{60\ s}{1\ min}\ \frac{1\ rev}{2\pi\ rad} = 1.34 \times 10^3\ \frac{rev}{min}$ or rpm

$V_{CB} = V_{CA} + V_{AB}$

$V_{OC} = V_{OE} + V_{EC}$

③ $1 = 0.5 + 0.5$

② $-0.5 = 0.5 - 1$

① $0 = 0.5 - 0.5$

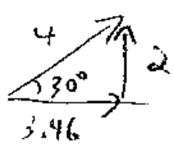
$\vec{V}_{PE} = \vec{V}_{PA} + \vec{V}_{AE}$

$\vec{V}_{BC} = \vec{V}_{BE} + \vec{V}_{EC}$

$\vec{V}_{CE} = 2\hat{j}$

$\vec{V}_{BE} = 3.46\hat{i} + 2\hat{j}$

$\vec{V}_{BC} = \vec{V}_{BE} - \vec{V}_{CE}$



$\vec{V}_{BC} = 1.46\hat{i} + 2\hat{j}$

$\tan\theta = \frac{2}{1.46} \Rightarrow \boxed{\theta = 53.9°}$

$$\vec{V}_{OC} = \vec{V}_{OE} + \vec{V}_{EC}$$

CB   CA   A B

$$V_{EC} = -V_{CE}$$

$$0 = 0.5 \tfrac{m}{s} - 0.5 \tfrac{m}{s}$$

$$V_{OC} = V_{OE} + V_{EC} = V_{OE} - V_{CE}$$

$$0.5 - 1.0 \tfrac{m}{s} = -0.5 \tfrac{m}{s}$$

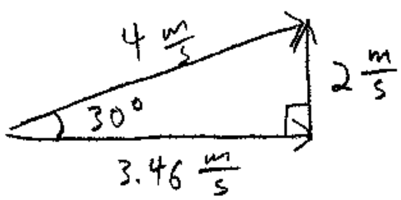
$$\vec{V}_{BC} = \vec{V}_{BE} + \vec{V}_{EC} = \vec{V}_{BE} - \vec{V}_{CE}$$

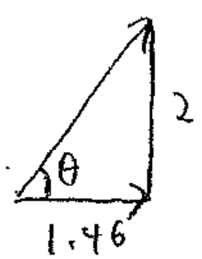
$$(3.46 - 2)\hat{i} + 2\hat{j}$$

$$\vec{V}_{CE} = 2 \tfrac{m}{s} \hat{i}$$

$$\vec{V}_{BE} = 3.46 \tfrac{m}{s} \hat{i} + 2 \tfrac{m}{s} \hat{j}$$

$$\vec{V}_{BC} = 1.46 \tfrac{m}{s} \hat{i} + 2 \tfrac{m}{s} \hat{j}$$





$$\boxed{\theta = 53.9^\circ}$$

$$\Sigma F_x = m a_x \quad , \quad \Sigma F_y = 0$$

$$N - W\cos\theta = 0 \qquad f_K = \mu_K N$$

$$f_K - W\sin\theta = ma \qquad W = mg$$

$$N = W\cos\theta \Rightarrow f_K = \mu_K W\cos\theta$$

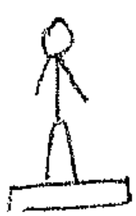
$$\mu_K W\cos\theta - W\sin\theta = ma$$

$$\mu_K \cancel{m} g\cos\theta - \cancel{m} g\sin\theta = \cancel{m} a$$

$$a = \mu_K g\cos\theta - g\sin\theta$$

$$= 0.1 \times 9.8 \cos 30^\circ - 9.8 \sin 30^\circ$$

$$= 0.849 - 4.9 = -4.1 \frac{m}{s^2}$$



$$N - W = ma$$

$$N = ma + W$$

$$N = ma + mg$$

$$N = m(a + g)$$

$$1\text{ lb} = 4.45\text{ N}$$

$$N = 200\text{ lb} = 890\text{ N}$$

$$W = mg = 712\text{ N}$$

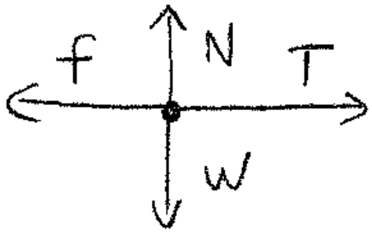
$$m = \frac{712\text{ N}}{9.8 \frac{m}{s^2}} = 72.7\text{ kg}$$

$$\frac{N}{m} = a + g$$

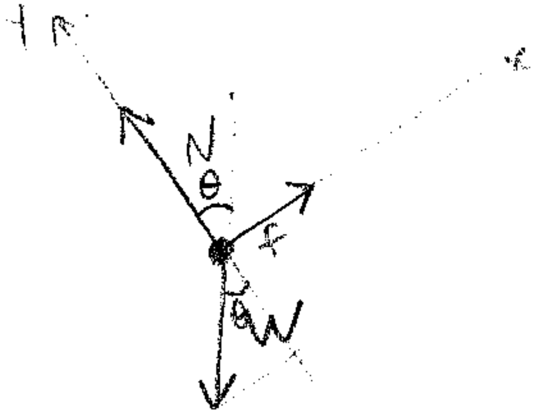
$$a = \frac{N}{m} - g$$

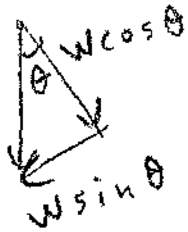
$$a = \frac{890\text{ N}}{72.7\text{ kg}} - 9.8 \frac{m}{s^2}$$

$$= 2.4 \frac{m}{s^2}$$



$$f_s \le \mu_s N$$





$$\sum \vec{F} = 0 \qquad \sum F_x = 0 \ , \ \sum F_y = 0$$

$$f_s - W\sin\theta = 0 \ , \quad f_s = \mu_s N$$

$$N - W\cos\theta = 0 \ , \quad W = mg$$

$$\mu_s N - W\sin\theta = 0$$

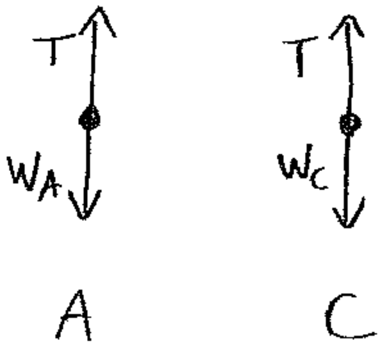
$$N = W\cos\theta$$

$$\mu_s W\cos\theta - W\sin\theta = 0$$

$$\mu_s \cancel{W}\cos\theta = \cancel{W}\sin\theta$$

$$\mu_s = \frac{\sin\theta}{\cos\theta} = \tan\theta$$

$$\boxed{\theta = \arctan \mu_s}$$



$$W_A = m_A g$$

$$W_C = m_C g$$

$$\sum \vec{F} = m\vec{a}$$

$$T - W_A = m_A a_A$$

$$T - W_C = m_C a_C$$

$$T - m_A g = m_A a_A \qquad a_A = -a_C$$

$$T - m_C g = m_C a_C = -m_C a_A$$

$$T - m_A g = m_A a_A \Rightarrow T = m_A a_A + m_A g$$

$$T - m_C g = -m_C a_A$$

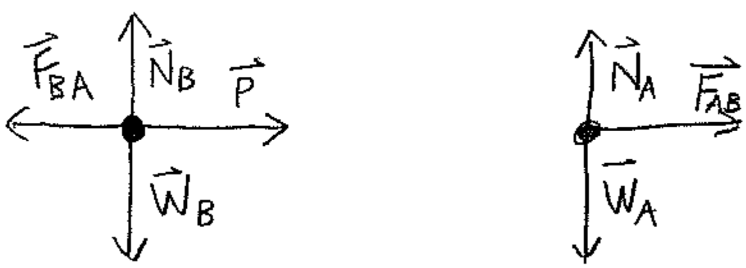
$$m_A a_A + m_A g - m_C g = -m_C a_A$$

$$m_A a_A + m_C a_A = m_C g - m_A g$$

$$a_A (m_A + m_C) = g(m_C - m_A)$$

$$a_A = \frac{g(m_C - m_A)}{m_A + m_C} = 9.8\,\frac{m}{s^2}\,\frac{0.150 - 0.10}{0.15 + 0.10}$$

$$|N| = W = mg$$



$$a_A = a_B$$

B A

$$\Sigma \vec{F} = m\vec{a} \qquad \Sigma \vec{F}_y = N_B - W_B = 0$$

$$\vec{P} + \vec{F}_{BA} = m_B \vec{a}_B \qquad N_A - W_A = 0$$

$$\Sigma F_B = P - F_{AB} = m_B a_B = m_B a$$

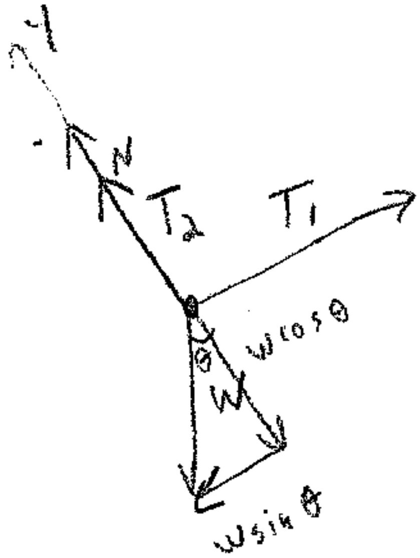
$$\Sigma F_A = F_{AB} = m_A a_A = m_A a$$

$$m_A = \frac{1}{2} m_B$$

$$P - F_{AB} = m_B a$$

$$F_{AB} = m_A a = \frac{1}{2} m_B a$$

$$P - \frac{1}{2} m_B a = m_B a \Rightarrow P = \frac{3}{2} m_B a$$



$$\Sigma F_y = 0$$

$$N + T_2 - W\cos\theta = 0$$

$$T_2 = W\cos\theta - N$$

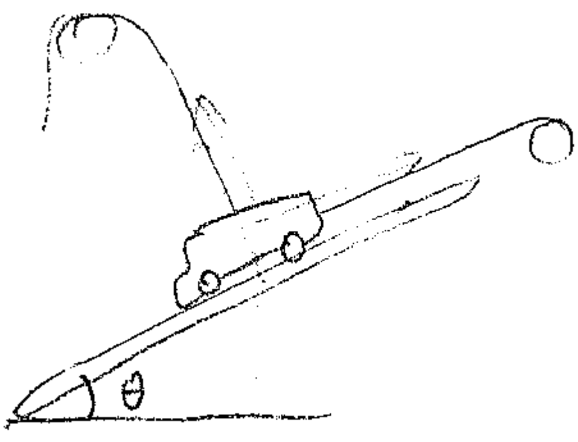
$$T_1 = W\sin\theta$$

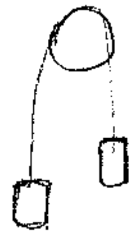
$$W = mg$$

$$10\,g \; \frac{1\,kg}{1000\,g}$$

$$F = ma$$

$$\cancel{m}g = \cancel{m}a$$





m_A $\quad$ m_B

$$T_A = T_B$$

$$m_A = m_B = m$$

If $a_A = a_B = 0$

$$T - W = 0$$

$$T_A - W_A = m a_A$$

$$T_B - W_B = m a_B$$

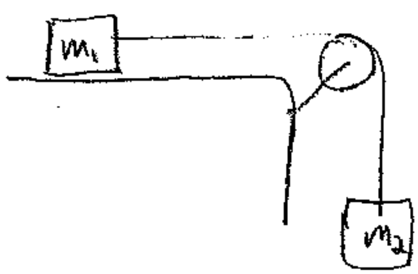
$$\boxed{a_A = -a_B}$$

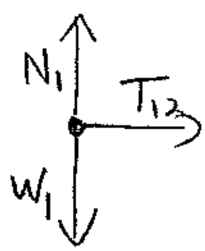
$$T - m g = m_A a_A$$

$$T - m g = m_B a_B$$

$$a_A = a_B$$

$$|T_{12}| = |T_{21}| = T$$





$$\Sigma \vec{F} = m\vec{a} \Rightarrow \Sigma F_x = m a_x, \quad \Sigma F_y = m a_y$$

$$T = m_1 a_1 \qquad N_1 - W_1 = 0$$

$$T - W_2 = m_2 a_2 \Rightarrow T = -m_1 a_2$$

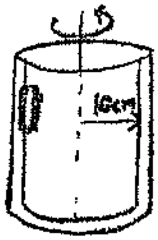
$$T - m_2 g = m_2 a_2$$

$$a_1 = -a_2$$

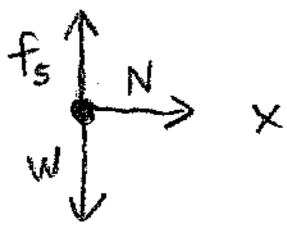
$$-m_1 a_2 - m_2 g = m_2 a_2$$

$$-m_1 a_2 - m_2 a_2 = m_2 g$$

3. [25 pts total] A rubber eraser is placed up against the wall of a rotating cylinder of radius 10 cm as shown in the diagram. The eraser has mass 0.021 kg and the coefficient of static friction between the eraser and the cylinder is 0.80 and the coefficient of kinetic friction between the eraser and the cylinder is 0.40.



a. [5pts] Assume the eraser does not slip. Draw the free body diagram of the eraser.



b. [8pts] What is the minimum constant angular velocity (in rpm) that the cylinder must maintain so that the eraser does not slip?

$$\Sigma \vec{F} = m\vec{a}, \quad \Sigma F_y = 0, \quad \Sigma F_r = m a_r$$

$$f_s - W = 0, \quad N = m a_r = m\frac{v^2}{r}$$

$$f_s \leq \mu_s N \qquad f_s = \mu_s N \qquad \mu_s N - W = 0$$

$$\Rightarrow N = \frac{W}{\mu_s} = \frac{mg}{\mu_s} = N$$

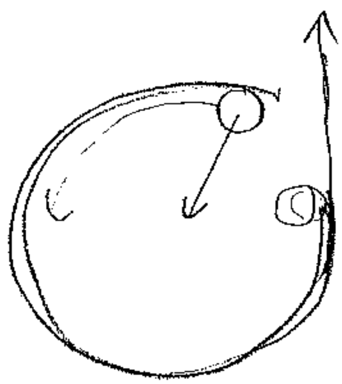
c. [6pts] Under the conditions of part b, what is the speed of the eraser?

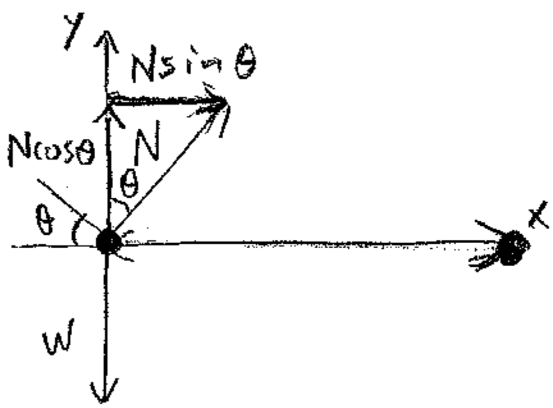
$$\frac{mg}{\mu_s} = m\frac{v^2}{r} \qquad v = \sqrt{\frac{rg}{\mu_s}} = 1.1\ \frac{m}{s} \quad (c)$$

$$11\ \frac{rad}{s} \cdot \frac{60\,s}{1\,min} \cdot \frac{1\,rev}{2\pi\,rad} = 106\ rpm \quad (b) \qquad \omega = \frac{v}{r} = \frac{1.1}{0.1} = 11\ \frac{rad}{s}$$

d. [6pts] Again in this situation, what is the acceleration (magnitude and direction) of the eraser?

$$a_r = \frac{v^2}{r} = \frac{1.1^2}{0.10} = 12.1\ \frac{m}{s^2}$$ towards the center of the cylinder





$$\sum \vec{F} = m\vec{a}$$

$$\sum F_y = 0$$

$$\sum F_r = m a_r$$

$$\sum F_r = m\frac{v^2}{r}$$

$$N\sin\theta = m\frac{v^2}{r}$$

$$N\cos\theta - W = 0$$

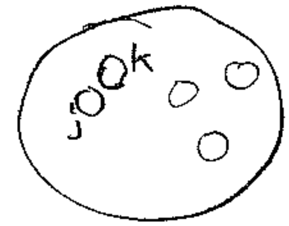
$$N\cos\theta = W = mg$$

$$N = \frac{mg}{\cos\theta}$$

$$\frac{mg\sin\theta}{\cos\theta} = m\frac{v^2}{r} \Rightarrow \cancel{m}g\tan\theta = \frac{\cancel{m}v^2}{r}$$

$$v^{\cancel{2}} = \sqrt{rg\tan\theta} = 13\ \frac{m}{s}$$

$$\frac{d\vec{p}_{tot}}{dt} = \sum_k \frac{d\vec{p}_k}{dt} = \sum_k \vec{F}_k$$



$$\vec{F}_k = \sum_{j \neq k} \vec{F}_{j\,on\,k} + \vec{F}_{ext\,on\,k}$$

$$\frac{d\vec{P}_{tot}}{dt} = \sum_k \sum_{j \neq k} \vec{F}_{j\,on\,k} + \sum_k \vec{F}_{ext\,on\,k}$$

$\nwarrow 0$

$$\vec{F}_{k\,on\,j} = -\vec{F}_{j\,on\,k}$$

$$\frac{d\vec{P}_{tot}}{dt} = \vec{F}_{net}$$

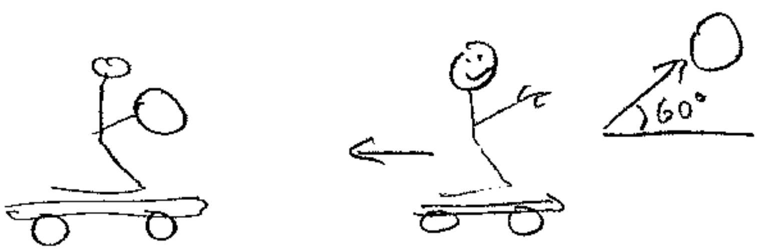
$$\vec{p}_i = \vec{p}_f \qquad V_{2i} = V \qquad m_1 = m_2$$

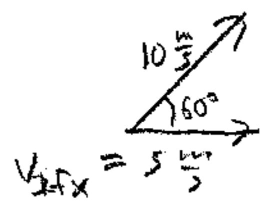
$$\cancel{m_1 V_{1i}} + m_2 V_{2i} = m_1 V_{1f} + m_2 V_{2f}$$

$$\cancel{m}\, V_{2i} = \cancel{m}\,(V_{1f} + V_{2f}) = V$$

$$\vec{p}_i = \vec{p}_f \Rightarrow p_{ix} = p_{fx} \qquad m_1 = 80\ kg \quad m_2 = 4\ kg$$

$$m_1 V_{1ix} + m_2 V_{2ix} = m_1 V_{1fx} + m_2 V_{2fx}$$





before

after

$$p_i = 0$$

$$0 = m_1 V_{1fx} + m_2 V_{2fx}$$

$$V_{1fx} = -\frac{m_2 V_{2fx}}{m_1}$$

$$V_{1fx} = \frac{4}{80}\,5 \neq 0.25\ \frac{m}{s}$$