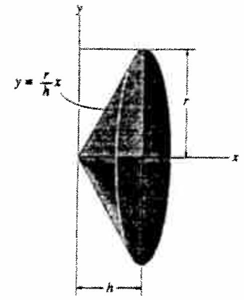
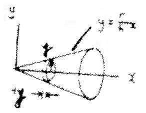
17-01. The right circular cone is formed by revolving the shaded area around the x axis. Determine the moment of inertia I_x and express the result in terms of the total mass m of the cone. The cone has a constant density ρ.



$$dm = \rho\, dV = \rho\left(\pi y^2\, dx\right)$$



$$m = \int_0^h \rho(\pi)\left(\frac{r^2}{h^2}\right)x^2\, dx = \rho\pi\left(\frac{r^2}{h^2}\right)\left(\frac{1}{3}\right)h^3 = \frac{1}{3}\rho\pi r^2 h$$

$$dI_x = \frac{1}{2}y^2\, dm$$

$$= \frac{1}{2}y^2\left(\rho\pi y^2\, dx\right)$$

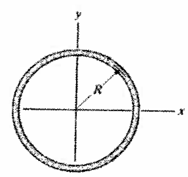
$$= \frac{1}{2}\rho(\pi)\left(\frac{r^4}{h^4}\right)x^4\, dx$$

$$I_x = \int_0^h \frac{1}{2}\rho(\pi)\left(\frac{r^4}{h^4}\right)x^4\, dx = \frac{1}{10}\rho\pi r^4 h$$

Thus

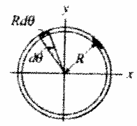
$$I_x = \frac{3}{10}m\,r^2 \quad \textbf{Ans}$$

17-02. Determine the moment of inertia of the thin ring about the z axis. The ring has a mass m.



$$I_z = \int_0^{2\pi} \rho\, A(R\, d\theta)R^2 = 2\pi\,\rho\, A\, R^3$$

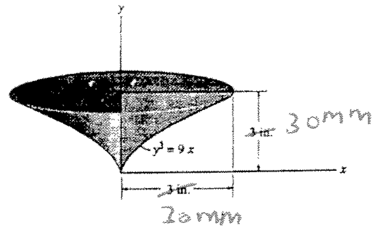
$$m = \int_0^{2\pi} \rho\, A\, R\, d\theta = 2\pi\,\rho\, A\, R$$

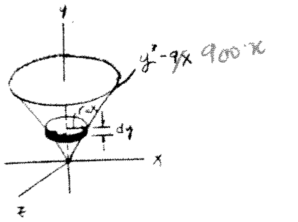


Thus,

$$I_z = m R^2 \quad \textbf{Ans}$$

17-03. The solid is formed by revolving the shaded area around the y axis. Determine the radius of gyration k_y. The specific weight of the material is $\gamma =$ ~~380 lb/ft³~~. 2 Mg/m³





The moment of inertia of the solid : The mass of the disk element $dm = \rho\pi x^2 dy = \frac{1}{81}\rho\pi y^6 dy$.

$$dI_y = \frac{1}{2}dm x^2$$

$$= \frac{1}{2}(\rho\pi x^2 dy)\, x^2$$

$$= \frac{1}{2}\rho\pi x^4 dy = \frac{1}{\cancel{2(9^4)}}\rho\pi y^{12} dy \quad = \frac{1}{2}\frac{1}{(900)^4}\rho\pi y^{12} dy$$

$$I_y = \int dI_y = \frac{1}{2(9^4)}\rho\pi\int_0^{30} y^{12} dy \quad = \frac{1}{26(900)^4}\rho\pi \frac{y^{13}}{13}\Big|_0^{30}$$

$$= 29.632\rho \quad = 29.632\times10\,\rho$$

The mass of the solid :

$$m = \int_m dm = \frac{1}{\cancel{81}}\rho\pi\int_0^3 y^6 dy = 12.\cancel{117}\rho \quad = \frac{1}{(900)^2}\rho\pi\int_0^{30} y^6 dy = \frac{1}{(900)^2}\rho\pi\frac{y^7}{7}\Big|_0^{30}$$

$$= 12.117\times10^3\rho$$

$$k_y = \sqrt{\frac{I_y}{m}} = \sqrt{\frac{\cancel{29.632\rho}}{12.117\rho}} = \cancel{1.56 \text{ in.}} \quad \textbf{Ans}$$

$$= \sqrt{\frac{29.632\times10^5\rho}{12.117\times10^3\rho}} = 15.57\text{ mm}$$

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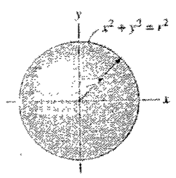
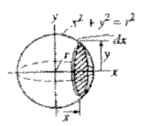
*17-04. Determine the moment of inertia I_x of the sphere and express the result in terms of the total mass m of the sphere. The sphere has a constant density ρ.



$$d I_x = \frac{y^2\, dm}{2}$$

$$dm = \rho\, dV = \rho(\pi y^2\, dx) = \rho\pi(r^2 - x^2)\, dx$$



$$d I_x = \frac{1}{2}\rho\pi(r^2 - x^2)^2\, dx$$

$$I_x = \int_{-r}^{r}\frac{1}{2}\rho\pi(r^2 - x^2)^2\, dx$$

$$= \frac{8}{15}\pi\rho r^5$$

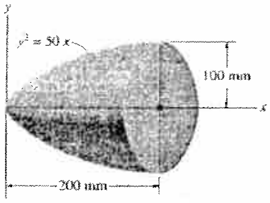
$$m = \int_{-r}^{r}\rho\pi(r^2 - x^2)\, dx$$

$$= \frac{4}{3}\rho\pi r^3$$

Thus,

$$I_x = \frac{2}{5}mr^2 \quad \textbf{Ans}$$

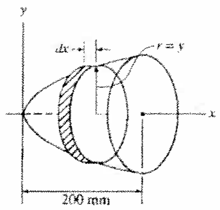
17-05. Determine the radius of gyration k_x of the paraboloid. The density of the material is $\rho = 5\ \text{Mg/m}^3$.



Differential Disk Element: The mass of the differential disk element is $dm = \rho dV = \rho\pi y^2\,dx = \rho\pi(50x)\,dx$. The mass moment of inertia of this element is $dI_x = \frac{1}{2}dmy^2 = \frac{1}{2}[\rho\pi(50x)\,dx](50x) = \frac{\rho\pi}{2}(2500x^2)\,dx$.

Total Mass: Performing the integration, we have

$$m = \int_m dm = \int_0^{200\text{ mm}} \rho\pi(50x)\,dx = \rho\pi(25x^2)\Big|_0^{200\text{ mm}} = 1(10^6)\rho\pi$$



Mass Moment of Inertia: Performing the integration, we have

$$I_x = \int dI_x = \int_0^{200\text{ mm}} \frac{\rho\pi}{2}(2500x^2)\,dx$$

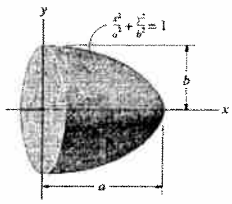
$$= \frac{\rho\pi}{2}\left(\frac{2500x^3}{3}\right)\Big|_0^{200\text{ mm}}$$

$$= 3.333(10^9)\rho\pi$$

The radius of gyration is

$$k_x = \sqrt{\frac{I_x}{m}} = \sqrt{\frac{3.333(10^9)\rho\pi}{1(10^6)\rho\pi}} = 57.7\text{ mm} \quad \textbf{Ans}$$

17-06. Determine the moment of inertia of the semiellipsoid with respect to the x axis and express the result in terms of the mass m of the semiellipsoid. The material has a constant density ρ.

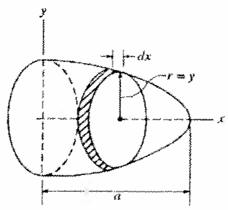


Differential Disk Element: Here, $y^2 = b^2\left(1 - \frac{x^2}{a^2}\right)$. The mass of the differential disk element is $dm = \rho dV = \rho\pi y^2\,dx = \rho\pi b^2\left(1 - \frac{x^2}{a^2}\right)dx$. The mass moment of inertia of this element is $dI_x = \frac{1}{2}dmy^2 = \frac{1}{2}\left[\rho\pi b^2\left(1 - \frac{x^2}{a^2}\right)dx\right]\left[b^2\left(1 - \frac{x^2}{a^2}\right)\right] = \frac{\rho\pi b^4}{2}\left(\frac{x^4}{a^4} - \frac{2x^2}{a^2} + 1\right)dx$.

Total Mass: Performing the integration, we have

$$m = \int_m dm = \int_0^a \rho\pi b^2\left(1 - \frac{x^2}{a^2}\right)dx = \rho\pi b^2\left(x - \frac{x^3}{3a^2}\right)\Big|_0^a$$

$$= \frac{2}{3}\rho\pi ab^2$$



Mass Moment of Inertia: Performing the integration, we have

$$I_x = \int dI_x = \int_0^a \frac{\rho\pi b^4}{2}\left(\frac{x^4}{a^4} - \frac{2x^2}{a^2} + 1\right)dx$$

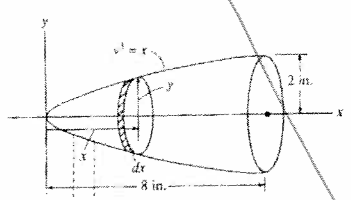
$$= \frac{\rho\pi b^4}{2}\left(\frac{x^5}{5a^4} - \frac{2x^3}{3a^2} + x\right)\Big|_0^a$$

$$= \frac{4}{15}\rho\pi ab^4$$

The mass moment of inertia expressed in terms of the total mass is

$$I_x = \frac{2}{5}\left(\frac{2}{3}\rho\pi ab^2\right)b^2 = \frac{2}{5}mb^2 \quad \textbf{Ans}$$

17-07. Determine the radius of gyration k_x. The specific weight of the material is $\gamma = 380\ \text{lb/ft}^3$.



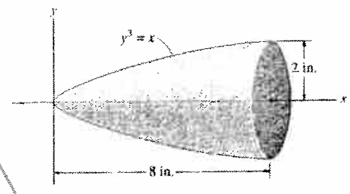
$$dm = \rho\, dV = \rho \pi y^2\, dx$$

$$d\,I_x = \frac{1}{2}(dm) y^2 = \frac{1}{2}\pi \rho y^4\, dx$$

$$I_x = \int_0^8 \frac{1}{2}\pi \rho x^{4/3}\, dx = 86.17\rho$$

$$m = \int_0^8 \pi \rho x^{2/3}\, dx = 60.32\rho$$

$$k_x = \sqrt{\frac{I_x}{m}} = \sqrt{\frac{86.17\rho}{60.32\rho}} = 1.20\ \text{in.} \quad \textbf{Ans}$$



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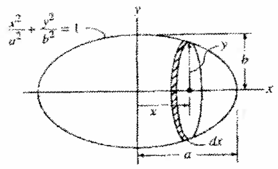
*17-08. Determine the moment of inertia of the ellipsoid with respect to the x axis and express the result in terms of the mass m of the ellipsoid. The material has a constant density ρ.



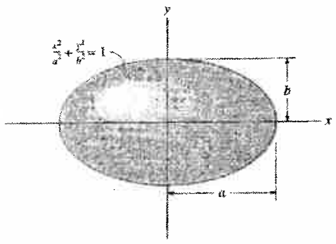
$$d\,I_x = \frac{y^2 dm}{2}$$

$$m = \int_V \rho\, dV = \int_{-a}^{a} \rho \pi b^2 \left(1 - \frac{x^2}{a^2}\right) dx = \frac{4}{3}\pi \rho a b^2$$

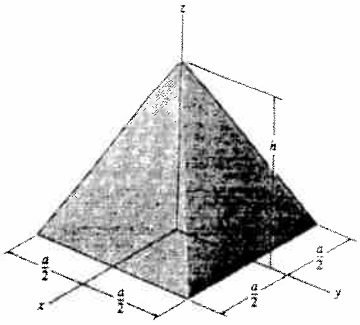
$$I_x = \int_{-a}^{a} \frac{1}{2}\rho \pi b^4 \left(1 - \frac{x^2}{a^2}\right)^2 dx = \frac{8}{15}\pi \rho a b^4$$

Thus,

$$I_x = \frac{2}{5} m b^2 \quad \textbf{Ans}$$



17-09. 8 Determine the moment of inertia of the homogeneous pyramid of mass m with respect to the z axis. The density of the material is ρ. *Suggestion:* Use a rectangular plate element having a volume of $dV = (2x)(2y)\,dz$.



$$dI_z = \frac{dm}{12}\left[(2y)^2 + (2y)^2\right] = \frac{2}{3}y^2\,dm$$

$$dm = \rho y^2\,dz$$

$$dI_z = \frac{2}{3}\rho y^4\,dz = \frac{2}{3}\rho(h-z)^4\left(\frac{a^4}{16h^4}\right)dz$$

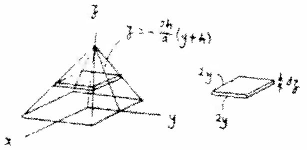
$$I_z = \frac{\rho}{24}\left(\frac{a^4}{h^4}\right)\int_0^h \left(h^4 - 4h^3z + 6h^2z^2 - 4hz^3 + z^4\right)dz = \frac{\rho}{24}\left(\frac{a^4}{h^4}\right)\left[h^5 - 2h^5 + 2h^5 - h^5 + \frac{1}{5}h^5\right]$$

$$= \frac{\rho a^4 h}{120}$$

$$m = \int_0^h \rho(h-z)^2\left(\frac{a^2}{4h^2}\right)dz = \frac{\rho a^2}{4h^2}\int_0^h \left(h^2 - 2hz + z^2\right)dz$$

$$= \frac{\rho a^2}{4h^2}\left[h^3 - h^3 + \frac{1}{3}h^3\right]$$

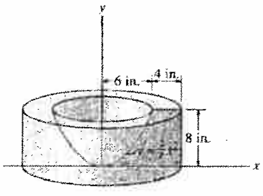
$$= \frac{\rho a^2 h}{12}$$

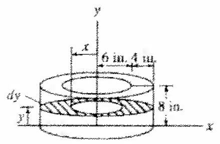


Thus,

$$I_z = \frac{m}{10}a^2 \qquad \textbf{Ans}$$

17-10. The concrete shape is formed by rotating the shaded area about the y axis. Determine the moment of inertia I_y. The specific weight of concrete is $\gamma = 150\ \text{lb/ft}^3$.





$$dI_y = \frac{1}{2}(dm)(10)^2 - \frac{1}{2}(dm)x^2$$

$$= \frac{1}{2}[\pi\rho(10)^2\,dy](10)^2 - \frac{1}{2}\pi\rho x^2\,dy\,x^2$$

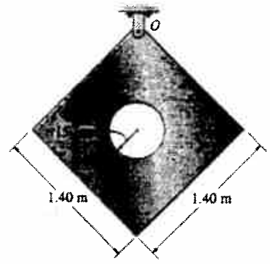
$$I_y = \frac{1}{2}\pi\rho\left[\int_0^8 (10)^4\,dy - \int_0^8 \left(\frac{9}{2}\right)^2 y^2\,dy\right]$$

$$= \frac{\frac{1}{2}\pi(150)}{32.2(12)^3}\left[(10)^4(8) - \left(\frac{9}{2}\right)^2\left(\frac{1}{3}\right)(8)^3\right]$$

$$= 324.1\ \text{slug}\cdot\text{in}^2$$

$$I_y = 2.25\ \text{slug}\cdot\text{ft}^2 \qquad \textbf{Ans}$$

17-~~11~~9. Determine the moment of inertia of the thin plate about an axis perpendicular to the page and passing through the pin at O. The plate has a hole in its center. Its thickness is 50 mm, and the material has a density of $\rho = 50\ \text{kg/m}^3$.



$$I_G = \frac{1}{12}\left[50(1.4)(1.4)(0.05)\right]\left[(1.4)^2 + (1.4)^2\right] - \frac{1}{2}\left[50(\pi)(0.15)^2(0.05)\right](0.15)^2$$

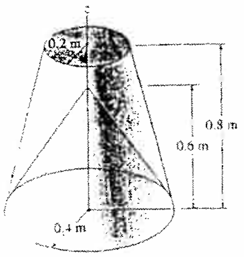
$$= 1.5987\ \text{kg}\cdot\text{m}^2$$

$$I_O = I_G + md^2$$

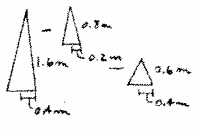
$$m = 50(1.4)(1.4)(0.05) - 50(\pi)(0.15)^2(0.05) = 4.7233\ \text{kg}$$

$$I_O = 1.5987 + 4.7233(1.4\sin 45^\circ)^2 = 6.23\ \text{kg}\cdot\text{m}^2 \qquad \textbf{Ans}$$

*17-~~12~~10. Determine the moment of inertia I_z of the frustum of the cone which has a conical depression. The material has a density of $200\ \text{kg/m}^3$.

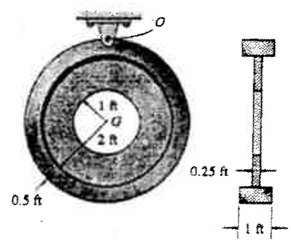


$$I_z = \frac{3}{10}\left[\frac{1}{3}\pi(0.4)^2(1.6)(200)\right](0.4)^2 - \frac{3}{10}\left[\frac{1}{3}\pi(0.2)^2(0.8)(200)\right](0.2)^2 - \frac{3}{10}\left[\frac{1}{3}\pi(0.4)^2(0.6)(200)\right](0.4)^2$$



$$I_z = 1.53\ \text{kg}\cdot\text{m}^2 \qquad \textbf{Ans}$$

17-13. Determine the moment of inertia of the assembly about an axis which is perpendicular to the page and passes through the center of mass G. The material has a specific weight of $\gamma = 90\ \text{lb/ft}^3$.

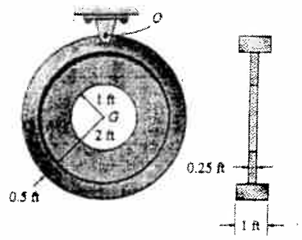


$$I_G = \frac{1}{2}\left[\left(\frac{90}{32.2}\right)\pi(2.5)^2(1)\right](2.5)^2 - \frac{1}{2}\left[\left(\frac{90}{32.2}\right)\pi(2)^2(1)\right](2)^2$$

$$+\frac{1}{2}\left[\left(\frac{90}{32.2}\right)\pi(2)^2(0.25)\right](2)^2 - \frac{1}{2}\left[\left(\frac{90}{32.2}\right)\pi(1)^2(0.25)\right](1)^2$$

$$= 118\ \text{slug}\cdot\text{ft}^2 \qquad \textbf{Ans}$$

17-14. Determine the moment of inertia of the assembly about an axis which is perpendicular to the page and passes through point O. The material has a specific weight of $\gamma = 90\ \text{lb/ft}^3$.



$$I_G = \frac{1}{2}\left[\left(\frac{90}{32.2}\right)\pi(2.5)^2(1)\right](2.5)^2 - \frac{1}{2}\left[\left(\frac{90}{32.2}\right)\pi(2)^2(1)\right](2)^2$$

$$+\frac{1}{2}\left[\left(\frac{90}{32.2}\right)\pi(2)^2(0.25)\right](2)^2 - \frac{1}{2}\left[\left(\frac{90}{32.2}\right)\pi(1)^2(0.25)\right](1)^2$$

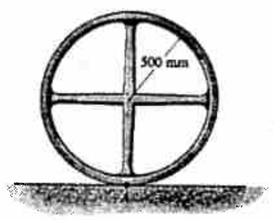
$$= 117.72\ \text{slug}\cdot\text{ft}^2$$

$$I_O = I_G + md^2$$

$$m = \left(\frac{90}{32.2}\right)\pi(2^2 - 1^2)(0.25) + \left(\frac{90}{32.2}\right)\pi(2.5^2 - 2^2)(1) = 26.343\ \text{slug}$$

$$I_O = 117.72 + 26.343(2.5)^2 = 282\ \text{slug}\cdot\text{ft}^2 \qquad \textbf{Ans}$$

17-~~15~~11. The wheel consists of a thin ring having a mass of 10 kg and four spokes made from slender rods, each having a mass of 2 kg. Determine the wheel's moment of inertia about an axis perpendicular to the page and passing through point A.



$$I_A = I_0 + md^3$$

$$= \left[2\left[\frac{1}{12}(4)(1)^2\right] + 10(0.5)^2\right] + 18(0.5)^2$$

$$= 7.67\ \text{kg}\cdot\text{m}^2 \qquad \textbf{Ans}$$

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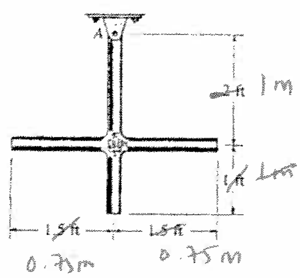
***17-~~16~~.** The slender rods have a ~~weight~~ mass of 3 ~~lb/ft~~ kg/m. Determine the moment of inertia of the assembly about an axis perpendicular to the page and passing through point A.



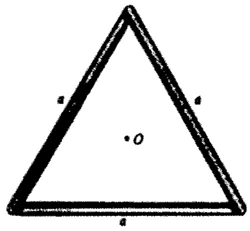
$$I = \frac{1}{3}\left(3\left(\frac{3}{32.2}\right)\right)(3)^2 + \frac{1}{12}\left(3\left(\frac{3}{32.2}\right)\right)(3)^2 + \left(3\left(\frac{3}{32.2}\right)\right)(2)^2$$

$$= 2.17\ \text{slug}\cdot\text{ft}^2 \qquad \textbf{Ans}$$

$$I = \frac{1}{3}(1.5(3))(1.5)^2 + \frac{1}{12}(1.5(3))(1.5)^2 + ([illegible]5)(3)([illegible])^2$$

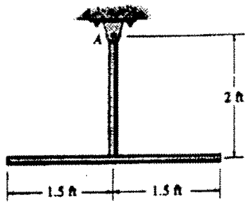
$$= 8.72\ \text{kgm}^2$$

17-17. **Each of the three rods has a mass m. Determine the moment of inertia of the assembly about an axis which is perpendicular to the page and passes through the center point O.**



$$I_O = 3\left[\frac{1}{12}ma^2 + m\left(\frac{a\sin 60^\circ}{3}\right)^2\right] = \frac{1}{2}ma^2$$ **Ans**

17-18. The slender rods have a weight of 3 lb/ft. Determine the moment of inertia of the assembly about an axis perpendicular to the page and passing through point A.

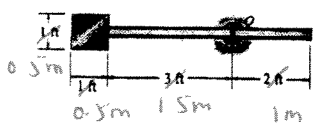


$$I_A = \frac{1}{3}\left[\frac{3(2)}{32.2}\right](2)^2 + \frac{1}{12}\left[\frac{3(3)}{32.2}\right](3)^2 + \left[\frac{3(3)}{32.2}\right](2)^2 = 1.58\ \text{slug}\cdot\text{ft}^2$$ **Ans**

13

17-19. The pendulum consists of a plate having a ~~weight~~ of 12 ~~lb~~ kg and a slender rod having a ~~weight of 4 lb.~~ mass of 4 kg Determine the radius of gyration of the pendulum about an axis perpendicular to the page and passing through point O.

mass



$$I_O = \Sigma I_G + md^2$$

$$= \frac{1}{12}\left(\frac{4}{\cancel{32.2}}\right)(5)^2 + \left(\frac{4}{\cancel{32.2}}\right)(0.5)^2 + \frac{1}{12}\left(\frac{12}{\cancel{32.2}}\right)(1^2+1^2) + \left(\frac{12}{\cancel{32.2}}\right)(3.5)^2$$

2.5 0.25 0.5² 0.5² 1.75

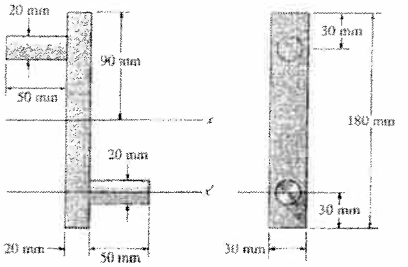
$= \cancel{4.917\ \text{slug}\cdot\text{ft}^2}$ ~~39.58 kg m²~~ 39.58 kg m²

$$m = \left(\frac{4}{\cancel{32.2}}\right) + \left(\frac{12}{\cancel{32.2}}\right) = \cancel{0.4969\ \text{slug}}$$ 16 kg

$$k_O = \sqrt{\frac{I_O}{m}} = \sqrt{\frac{4.917}{0.4969}} = 3.15\ \text{ft}$$ **Ans**

$$\sqrt{\frac{39.58}{16}} = 1.573\ \text{m}$$

*17-20 Determine the moment of inertia of the overhung crank about the x axis. The material is steel having a density of $\rho = 7.85$ Mg/m³.



Let m = mass of one handle.

$m = \rho(\pi r^2 h)$

$= (7.85 \times 10^3)\pi(0.010)^2(0.050)$

$= 0.1233$ kg

Let M = mass of bar.

$M = \rho(abc)$

$= (7.85 \times 10^3)(0.03)(0.18)(0.02)$

$= 0.8478$ kg

For the assembly,

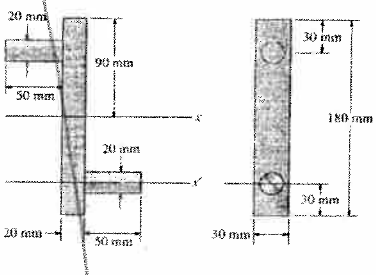
$$I_x = 2\left(\frac{1}{2}mr^2 + md^2\right) + \frac{1}{12}M(a^2 + b^2)$$

$$= 2\left[\frac{1}{2}(0.1233)(0.010)^2 + (0.1233)(0.060)^2\right]$$

$$+ \frac{1}{12}(0.8478)[(0.030)^2 + (0.18)^2]$$

$= 3.25 \times 10^{-3}$ kg · m² **Ans**

17-21. Determine the moment of inertia of the overhung crank about the x' axis. The material is steel having a density of $\rho = 7.85$ Mg/m³.



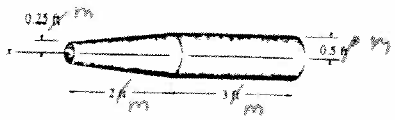
From 10-109, $m = 0.1233$ kg, $M = 0.8478$ kg, and $\bar{I}_x = 3.25 \times 10^{-3}$ kg·m⁻²,

$I_{x'} = I_c + (2m + M)d^2$

$= 3.25 \times 10^{-3} + [2(0.1233) + 0.8478](0.060)^2$

$= 7.20 \times 10^{-3}$ kg · m² **Ans**

17-22. Determine the moment of inertia of the solid steel assembly about the x axis. Steel has a specific weight of $\gamma_{st} =$ ~~490 lb/ft³~~. 70 ~~Mg/m³~~ kN/m³

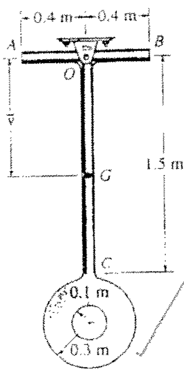


$$I_x = \frac{1}{2}m_1(0.5)^2 + \frac{3}{10}m_2(0.5)^2 - \frac{3}{10}m_3(0.25)^2$$

$$= \left[\frac{1}{2}\pi(0.5)^2(3)(0.5)^2 + \frac{3}{10}\left(\frac{1}{3}\right)\pi(0.5)^2(4)(0.5)^2 - \frac{3}{10}\left(\frac{1}{3}\right)\pi(0.25)^2(2)(0.25)^2\right]\left(\cancel{\frac{490}{32.2}}\right) \frac{70 \times 10^3}{9.81}$$

$=$ ~~5.64 slug · ft² Ans~~ 2645 kg · m²

17-23. The pendulum consists of two slender rods AB and OC which have a mass of 3 kg/m. The thin plate has a mass of 12 kg/m². Determine the location $\bar{y}$ of the center of mass G of the pendulum, then calculate the moment of inertia of the pendulum about an axis perpendicular to the page and passing through G.



$$\bar{y} = \frac{1.5(3)(0.75) + \pi(0.3)^2(12)(1.8) - \pi(0.1)^2(12)(1.8)}{1.5(3) + \pi(0.3)^2(12) - \pi(0.1)^2(12) + 0.8(3)}$$

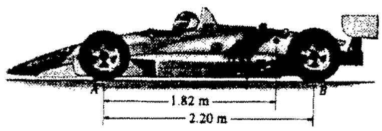
$$= 0.8878 \text{ m} = 0.888 \text{ m} \qquad \textbf{Ans}$$

$$I_G = \frac{1}{12}(0.8)(3)(0.8)^2 + 0.8(3)(0.8878)^2$$
$$+ \frac{1}{12}(1.5)(3)(1.5)^2 + 1.5(3)(0.75 - 0.8878)^2$$
$$+ \frac{1}{2}[\pi(0.3)^2(12)(0.3)^2 + [\pi(0.3)^2(12)](1.8 - 0.8878)^2$$
$$- \frac{1}{2}[\pi(0.1)^2(12)(0.1)^2 - [\pi(0.1)^2(12)](1.8 - 0.8878)^2$$

$$I_G = 5.61 \text{ kg}\cdot\text{m}^2 \qquad \textbf{Ans}$$

15

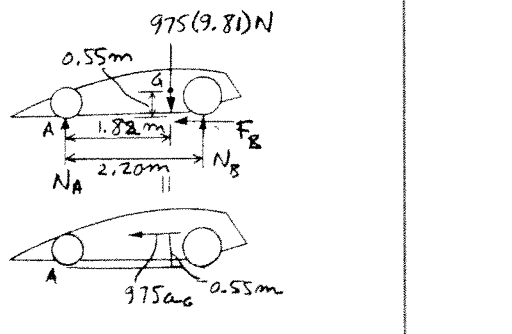
***17-24.** Determine the greatest possible acceleration of the 975-kg race car so that its front tires do not leave the ground or the tires slip on the track. The coefficients of static and kinetic friction are $\mu_s = 0.8$ and $\mu_k = 0.6$, respectively. Neglect the mass of the tires. The car has rear-wheel drive and the front tires are free to roll.



$\circlearrowleft + \Sigma M_A = \Sigma(M_k)_A;\quad -975(9.81)(1.82) + N_B(2.20) = 975(a_G)(0.55) \qquad (1)$

$+\uparrow \Sigma F_y = m(a_G)_y;\quad N_A + N_B - 975(9.81) = 0 \qquad (2)$

$\overset{+}{\leftarrow} \Sigma F_x = m(a_G)_x;\quad F_B = 975 a_G \qquad (3)$



Assume the rear wheels are on the verge of slipping.

$F_B = 0.8N_B$

Solving,

$a_G = 8.12 \text{ m/s}^2$

$N_B = 9890.8 \text{ N}$

$N_A = -326.1 \text{ N} < 0$

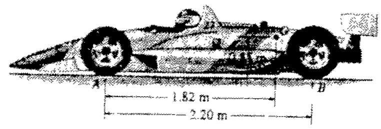
Front wheels lift off ground

Assume $N_A = 0$. Solving Eqs. (1) – (3),

$N_B = 9565 \text{ N}$

$a_G = 6.78 \text{ m/s}^2 \qquad$ **Ans**

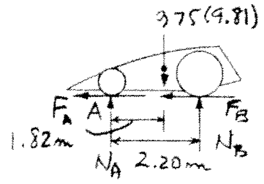
17-~~25~~16. Determine the greatest possible acceleration of the 975-kg race car so that its front wheels do not leave the ground or the tires slip on the track. The coefficients of static and kinetic friction are $\mu_s = 0.8$ and $\mu_k = 0.6$, respectively. Neglect the mass of the tires. The car has four-wheel drive.



$\circlearrowleft + \Sigma M_A = \Sigma (M_k)_A;\qquad -975(9.81)(1.82) + N_B(2.20) = 975(a_G)(0.55)$

$+\uparrow \Sigma F_y = m(a_G)_y;\qquad N_A + N_B - 975(9.81) = 0$

$\overset{+}{\leftarrow} \Sigma F_x = m(a_G)_x;\qquad F_A + F_B = 975a_G$



Assume all the wheels are on the verge of slipping.

$F_A = 0.8N_A$

$F_B = 0.8N_B$

Solving,

$a_G = 7.848\ \text{m/s}^2$

$N_B = 9825.6\ \text{N}$

$N_A = -261\ \text{N} < 0$

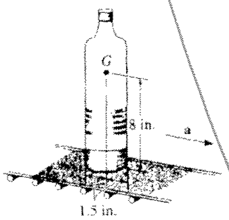
Front wheels lift off ground.

Assume $N_A = 0$ $(F_A = 0)$. Solving,

$N_B = 9565\ \text{N}$

$a_G = 6.78\ \text{m/s}^2$ **Ans**

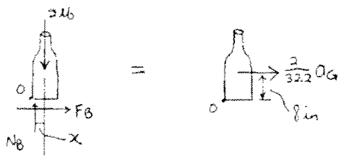
17-26. The 2-lb bottle rests on the check-out conveyor at a grocery store. If the coefficient of static friction is $\mu_s = 0.2$, determine the largest acceleration the conveyor can have without causing the bottle to slip or tip. The center of gravity is at G.



$\xrightarrow{+} \Sigma F_x = m(a_G)_x; \quad F_B = \frac{2}{32.2} a_G$

$+\uparrow \Sigma F_y = m(a_G)_y; \quad N_B - 2 = 0$

$\curvearrowleft + \Sigma M_O = \Sigma (M_K)_O; \quad 2x = \frac{2}{32.2} a_G (8)$



Assume bottle is about to slip.

$N_B = 2\text{ lb}, \quad F_B = 0.2(2) = 0.4\text{ lb}$

$a_G = 6.44\text{ ft/s}^2, \quad x = 1.6\text{ in.} > 1.5\text{ in.}$

Bottle will tip before slipping.

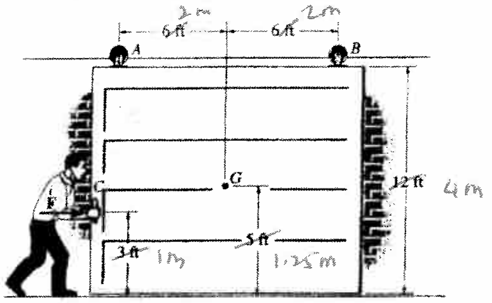
Set $x = 1.5$ in.

$N_B = 2\text{ lb}, \quad a_G = 6.04\text{ ft/s}^2$ **Ans**

$F_B = 0.375\text{ lb} < 0.4\text{ lb}$ **(O.K!)**

30 1000 N

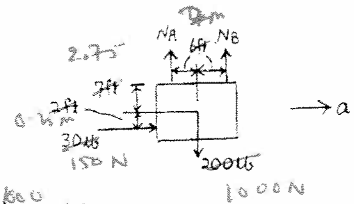
17-~~31~~. The door has a weight of ~~200 lb~~ and a center of gravity at G. Determine how far the door moves in 2 s, starting from rest, if a man pushes on it at C with a horizontal force F = 30 lb. Also, find the vertical reactions at the rollers A and B. 150 N



150 1000

$$\xrightarrow{+} \Sigma F_x = m(a_G)_x; \qquad \cancel{30} = \left(\frac{200}{32.2}\right)a_G$$

9.81



$$a_G = \cancel{4.83\text{ ft/s}^2}$$

1.47 m/s²

4 1000 150 1000 1.47

$$\circlearrowleft + \Sigma M_A = \Sigma(M_k)_A; \qquad N_B(\cancel{12}) - \cancel{200}(\cancel{6}) + \cancel{30}(\cancel{9}) = \left(\frac{200}{\cancel{32.2}}\right)(4.83)(\cancel{7})$$

2 3 9.81 2.75

$$N_B = \cancel{95.0\text{ lb}} \qquad \textbf{Ans}$$

490 N

$$+\uparrow \Sigma F_y = m(a_G)_y; \qquad N_A + \cancel{95.0} - \cancel{200} = 0$$

490 1000

$$N_A = \cancel{105\text{ lb}} \qquad \textbf{Ans}$$

510 N

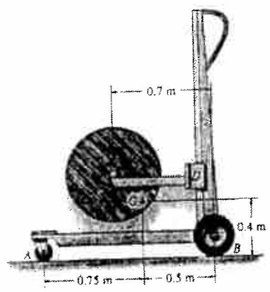
$$(\xrightarrow{+}) \qquad s = s_0 + v_0 t + \frac{1}{2}a_G t^2$$

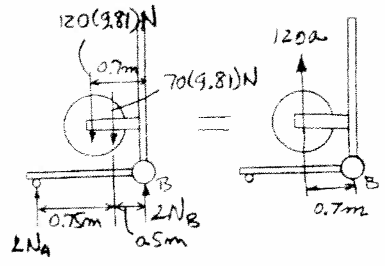
1.47

$$s = 0 + 0 + \frac{1}{2}(\cancel{4.83})(2)^2 = \cancel{9.66}\text{ ft} \qquad \textbf{Ans}$$

2.94 m

17-30. The lift truck has a mass of 70 kg and mass center at G. Determine the largest upward acceleration of the 120-kg spool so that no reaction of the wheels on the ground exceeds 600 N.





Assume $N_A = 600$ N.

343.35 824.04 1500

$$\circlearrowleft + \Sigma M_B = \Sigma (M_k)_B; \quad 70(9.81)(0.5) + 120(9.81)(0.7) - 2(600)(1.25) = -120a(0.7)$$

$$a = 3.960 \text{ m/s}^2$$

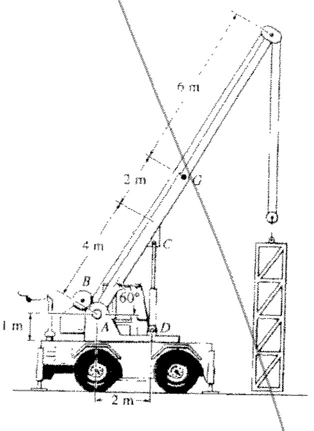
$$+\uparrow \Sigma F_y = m(a_G)_y; \quad 2(600) + 2N_B - 120(9.81) - 70(9.81) = 120(3.960)$$

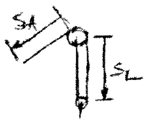
1177.2 686.7

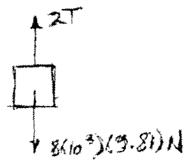
$$N_B = 570 \text{ N} < 600\text{N} \quad \text{OK}$$

Thus $a = 3.96$ m/s^2 **Ans**

17-27. The assembly has a mass of 8 Mg and is hoisted using the boom and pulley system. If the winch at B draws in the cable with an acceleration of 2 m/s^2, determine the compressive force in the hydraulic cylinder needed to support the boom. The boom has a mass of 2 Mg and mass center at G.







$$s_B + 2s_L = l$$

$$a_B = -2a_L$$

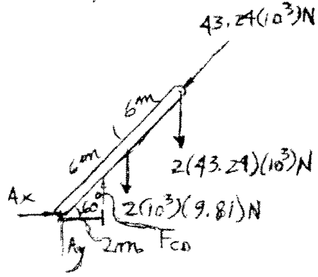
$$2 = -2a_L$$

$$a_L = -1 \text{ m/s}^2$$

Assembly:

$$+\uparrow \Sigma F_y = m\,a_y; \qquad 2T - 8(10^3)(9.81) = 8(10^3)(1)$$

$$T = 43.24 \text{ kN}$$

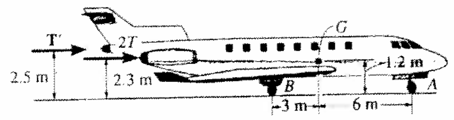


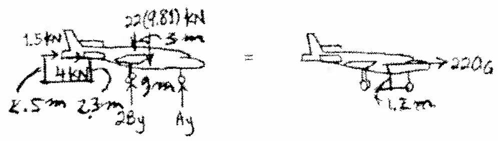
Boom:

$$\circlearrowleft + \Sigma M_A = 0; \qquad F_{CD}(2) - 2(10^3)(9.81)(6\cos 60°) - 2(43.24)(10^3)(12\cos 60°) = 0$$

$$F_{CD} = 289 \text{ kN} \qquad \textbf{Ans}$$

***17-28.** The jet aircraft has a total mass of 22 Mg and a center of mass at G. Initially at take-off the engines provide a thrust $2T = 4$ kN and $T' = 1.5$ kN. Determine the acceleration of the plane and the normal reactions on the nose wheel and each of the *two* wing wheels located at B. Neglect the mass of the wheels and, due to low velocity, neglect any lift caused by the wings.





$\xrightarrow{+} \Sigma F_x = ma_x; \quad 1.5 + 4 = 22a_G$

$+\uparrow \Sigma F_y = 0; \quad 2B_y + A_y - 22(9.81) = 0$

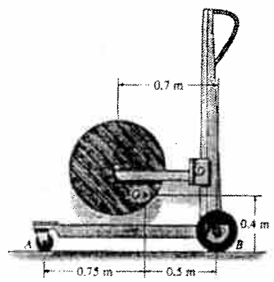
$\circlearrowleft + \Sigma M_B = \Sigma (M_K)_B; \quad -4(2.3) - 1.5(2.5) - 22(9.81)(3) + A_y(9) = -22a_G(1.2)$

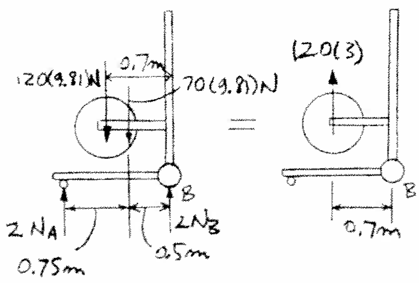
$A_y = 72.6$ kN **Ans**

$B_y = 71.6$ kN **Ans**

$a_G = 0.250\ \text{m/s}^2$ **Ans**

17-29. The lift truck has a mass of 70 kg and mass center at G. If it lifts the 120-kg spool with an acceleration of 3 m/s^2, determine the reactions of each of the four wheels on the ground. The loading is symmetric. Neglect the mass of the movable arm CD.





$\circlearrowleft + \Sigma M_B = \Sigma (M_k)_B; \quad 70(9.81)(0.5) + 120(9.81)(0.7) - 2N_A(1.25) = -120(3)(0.7)$

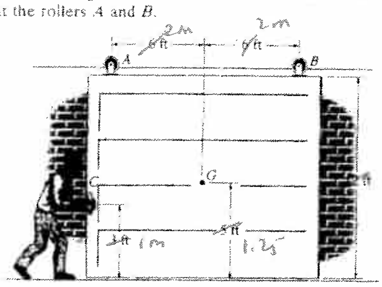
$N_A = 567.76\ \text{N} = 568\ \text{N}$ **Ans**

$+\uparrow \Sigma F_y = m(a_G)_y; \quad 2(567.76) + 2N_B - 120(9.81) - 70(9.81) = 120(3)$

$N_B = 544\ \text{N}$ **Ans**

21 1000N 4m

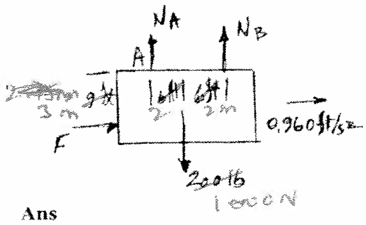
*17-~~32~~. The door has a weight of ~~200 lb~~ and a center of gravity at G. Determine the constant force F that must be applied to the door to push it open 12 ft to the right in 5 s, starting from rest. Also, find the vertical reactions at the rollers A and B.



$$(\xrightarrow{+})\ s = s_0 + v_0 t + \frac{1}{2}a_c t^2$$

$$4 \quad \cancel{12} = 0 + 0 + \frac{1}{2}a_c(5)^2$$

$$a_c = \cancel{0.960\ \text{ft/s}^2} \quad 0.32\ \text{m/s}^2$$



$$\xrightarrow{+} \Sigma F_x = m(a_G)_x; \quad F = \frac{\cancel{200}\ 1000}{\cancel{32.2}\ 9.81}(\cancel{0.960}\ 0.32)$$

$$F = \cancel{5.9627\ \text{lb} = 5.96}\ \text{lb} \quad = 32.62\ \text{N} \qquad \textbf{Ans}$$

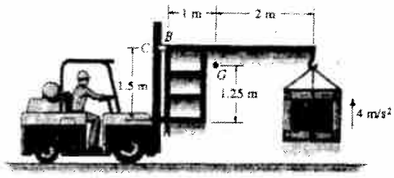
$$\curvearrowleft + \Sigma M_A = \Sigma(M_k)_A; \quad N_B(\cancel{12}\ 4) - \cancel{200}\ 1000(\cancel{6}\ 2) + \cancel{5.9627}\ 32.62(\cancel{9}\ 3) = \frac{\cancel{200}\ 1000}{\cancel{32.2}\ 9.81}(\cancel{0.960}\ 0.32)(\cancel{7}\ 2.75)$$

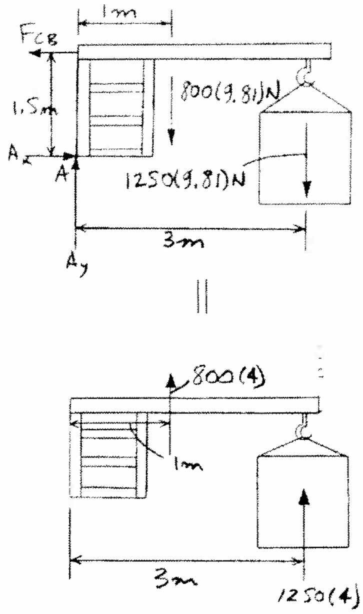
$$N_B = \cancel{99.0\ \text{lb}} \quad 498\ \text{N} \qquad \textbf{Ans}$$

$$+\uparrow \Sigma F_y = m(a_G)_y; \quad N_A + \cancel{99.0}\ 498 - \cancel{200}\ 1000 = 0$$

$$N_A = \cancel{101\ \text{lb}} \quad 502\ \text{N} \qquad \textbf{Ans}$$

17-33. The fork lift has a boom with a mass of 800 kg and a mass center at G. If the vertical acceleration of the boom is 4 m/s^2, determine the horizontal and vertical reactions at the pin A and on the short link BC when the 1.25-Mg load is lifted.





$\circlearrowleft + \Sigma M_A = \Sigma (M_k)_A$; $\quad F_{CB}(1.5) - 800(9.81)(1) - 1250(9.81)(3) = 800(1)(4) + 1250(3)(4)$

$F_{CB} = 41\ 890 \text{ N} = 41.9 \text{ kN}$ **Ans**

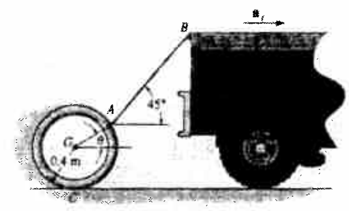
$\xrightarrow{+} \Sigma F_x = m(a_G)_x$; $\quad A_x - 41.9 = 0$

$A_x = 41.9 \text{ kN}$ **Ans**

$+\uparrow \Sigma F_y = m(a_G)_y$; $\quad A_y - 800(9.81) - 1250(9.81) = (800 + 1250)(4)$

$A_y = 28.3 \text{ kN}$ **Ans**

17-34. The pipe has a mass of 800 kg and is being towed behind the truck. If the acceleration of the truck is a_t = 0.5 m/s^2, determine the angle θ and the tension in the cable. The coefficient of kinetic friction between the pipe and the ground is $\mu_k = 0.1$.



$\xrightarrow{+} \Sigma F_x = ma_x$; $\quad -0.1N_C + T\cos 45° = 800(0.5)$

$+\uparrow \Sigma F_y = ma_y$; $\quad N_C - 800(9.81) + T\sin 45° = 0$

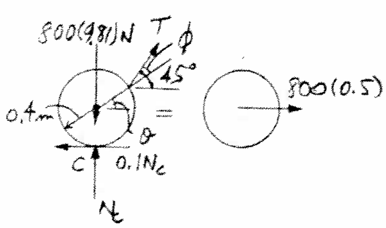
$\circlearrowleft + \Sigma M_G = 0$; $\quad -0.1N_C(0.4) + T\sin\phi(0.4) = 0$

$N_C = 6770.9 \text{ N}$

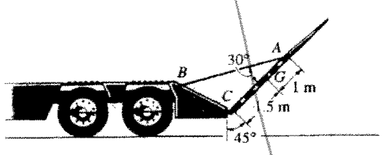
$T = 1523.24 \text{ N} = 1.52 \text{ kN}$ **Ans**

$\sin\phi = \dfrac{0.1(6770.9)}{1523.24} \qquad \phi = 26.39°$

$\theta = 45° - \phi = 18.6°$ **Ans**

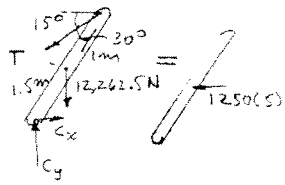


17-37. The drop gate at the end of the trailer has a mass of 1.25 Mg and mass center at G. If it is supported by the cable AB and hinge at C, determine the tension in the cable when the truck begins to accelerate at 5 m/s². Also, what are the horizontal and vertical components of reaction at the hinge C?



$\circlearrowleft + \Sigma M_C = \Sigma(M_k)_C;\qquad T\sin 30°(2.5) - 12\,262.5(1.5\cos 45°) = 1250(5)(1.5\sin 45°)$

$T = 15\,708.4 \text{ N} = 15.7 \text{ kN}$ **Ans**



$\overset{+}{\leftarrow} \Sigma F_x = m(a_G)_x;\qquad -C_x + 15\,708.4\cos 15° = 1250(5)$

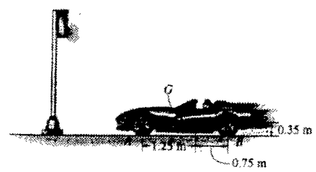
$C_x = 8.92 \text{ kN}$ **Ans**

$+\uparrow \Sigma F_y = m(a_G)_y;\qquad C_y - 12\,262.5 - 15\,708.4\sin 15° = 0$

$C_y = 16.3 \text{ kN}$ **Ans**

24

17-38. The sports car has a mass of 1.5 Mg and a center of mass at G. Determine the shortest time it takes for it to reach a speed of 80 km/h, starting from rest, if the engine only drives the rear wheels, whereas the front wheels are free rolling. The coefficient of static friction between the wheels and the road is $\mu_s = 0.2$. Neglect the mass of the wheels for the calculation. If driving power could be supplied to all four wheels, what would be the shortest time for the car to reach a speed of 80 km/h?



$\overset{+}{\leftarrow} \Sigma F_x = m(a_G)_x;\qquad 0.2N_A + 0.2N_B = 1500a_G \qquad (1)$

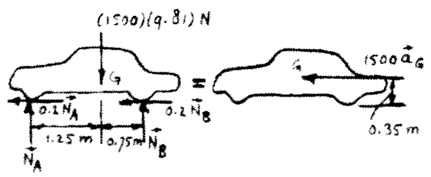
$+\uparrow \Sigma F_y = m(a_G)_y;\qquad N_A + N_B - 1500(9.81) = 0 \qquad (2)$

$\circlearrowleft + \Sigma M_G = 0;\qquad -N_A(1.25) + N_B(0.75) - (0.2N_A + 0.2N_B)(0.35) = 0 \qquad (3)$

For rear – wheel drive :

Set the friction force $0.2N_A = 0$ in Eqs. (1) and (3)

Solving yields :



$N_A = 5.18 \text{ kN} > 0 \quad \text{(OK)};\qquad N_B = 9.53 \text{ kN};\qquad a_G = 1.271 \text{ m/s}^2$

Since $v = 80 \text{ km/h} = 22.22 \text{ m/s}$, then

$(\overset{+}{\rightarrow})\qquad v = v_0 + a_G t$

$22.22 = 0 + 1.271t$

$t = 17.5 \text{ s}$ **Ans**

For 4 – wheel drive :

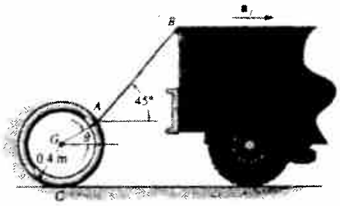
$N_A = 5.00 \text{ kN} > 0 \quad \text{(OK)};\qquad N_B = 9.71 \text{ kN};\qquad a_G = 1.962 \text{ m/s}^2$

Since $v_2 = 80 \text{ km/h} = 22.22 \text{ m/s}$, then

$v_2 = v_1 + a_G t, \qquad 22.22 = 0 + 1.962t$

$t = 11.3 \text{ s}$ **Ans**

17-35. The pipe has a mass of 800 kg and is being towed behind a truck. If the angle $\theta = 30°$, determine the acceleration of the truck and the tension in the cable. The coefficient of kinetic friction between the pipe and the ground is $\mu_k = 0.1$.



$\xrightarrow{+} \Sigma F_x = ma_x; \quad T\cos 45° - 0.1N_C = 800a$

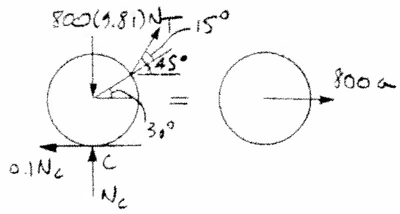
$+\uparrow \Sigma F_y = ma_y; \quad N_C - 800(9.81) + T\sin 45° = 0$

$\circlearrowleft + \Sigma M_G = 0; \quad T\sin 15°(0.4) - 0.1N_C(0.4) = 0$

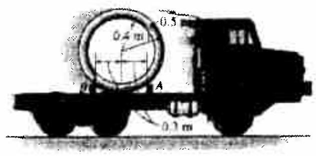
$N_C = 6164$ N

$T = 2382$ N $= 2.38$ kN **Ans**

$a = 1.33$ m/s^2 **Ans**



***17-36.** The pipe has a mass of 460 kg and is held in place on the truck bed using the two boards A and B. Determine the greatest acceleration of the truck so that the pipe begins to lose contact at A and the bed of the truck and starts to pivot about B. Assume board B will not slip on the bed of the truck, and the pipe is smooth. Also, what force does board B exert on the pipe during the acceleration?



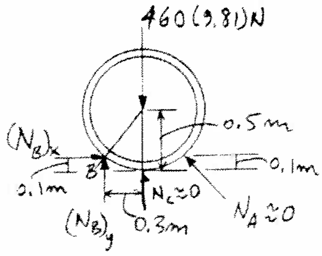
$\circlearrowleft + \Sigma M_B = \Sigma (M_k)_B; \quad 460(9.81)(0.30) = 460(a_G)(0.4)$

$a_G = 7.3575 = 7.36$ m/s^2 **Ans**

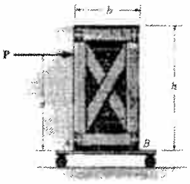
$\xrightarrow{+} \Sigma F_x = m(a_G)_x; \quad (N_B)_x = 460(7.3575) = 3384.45$ N

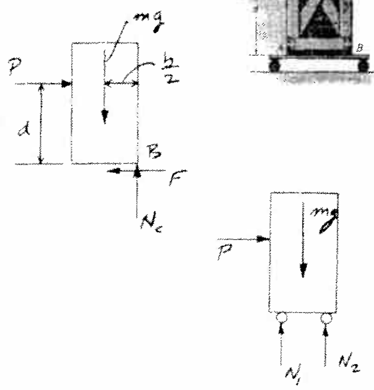
$+\uparrow \Sigma F_y = m(a_G)_y; \quad (N_B)_y - 460(9.81) = 4512.6$ N

$N_B = \sqrt{(3384.45)^2 + (4512.6)^2} = 5.64$ kN **Ans**



17-39. The crate of mass m is supported on a cart of negligible mass. Determine the maximum force P that can be applied a distance d from the cart bottom without causing the crate to tip on the cart.





Crate :

Require N_c to act at corner B for tipping.

$\curvearrowleft + \Sigma M_B = \Sigma(M_k)_B;\quad P(d) - mg\left(\frac{b}{2}\right) = m(a_G)\left(\frac{h}{2}\right)\qquad (1)$

System :

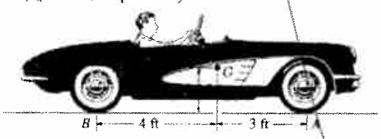
$\xrightarrow{+} \Sigma F_x = m(a_G)_x;\quad P = ma_G$

From Eq. (1) :

$$Pd - mg\left(\frac{b}{2}\right) = P\left(\frac{h}{2}\right)$$

$$P_{max} = \frac{mgb}{2\left(d - \frac{h}{2}\right)}\qquad \textbf{Ans}$$

*17-40. The car accelerates uniformly from rest to 88 ft/s in 15 seconds. If it has a weight of 3800 lb and a center of gravity at G, determine the normal reaction of *each wheel* on the pavement during the motion. Power is developed at the rear wheels, whereas the front wheels are free to roll. Neglect the mass of the wheels and take the coefficients of static and kinetic friction to be $\mu_s = 0.4$ and $\mu_k = 0.2$, respectively.

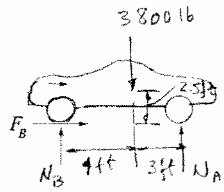


$$v = v_0 + a_c t$$

$$88 = 0 + a_c(15)$$

$$a_c = 5.867\text{ ft/s}^2$$

Assume no slipping



$\xrightarrow{+} \Sigma F_x = m(a_G)_x;\quad F_B = \frac{3800}{32.2}(5.867)$

$$F_B = 692\text{ lb}$$

$\curvearrowleft + \Sigma M_A = \Sigma(M_K)_A;\quad -3800(3) + N_B(7) = \frac{3800}{32.2}(5.867)(2.5)$

$$N_B = 1875.8\text{ lb}$$

$(F_B)_{max} = 1875.8(0.4) = 770\text{ lb} > 692\text{ lb}\qquad$ **(O.K!)**

$+\uparrow \Sigma F_y = 0;\quad N_B - 3800 + 1875.8 = 0$

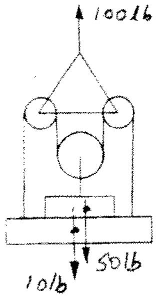
$$N_B = 1924\text{ lb}$$

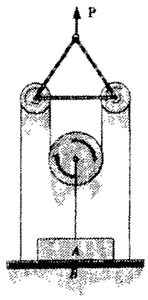
Normal reactions are

$$N'_A = \frac{1924}{2} = 962\text{ lb}\qquad \textbf{Ans}$$

$$N'_B = \frac{1875.8}{2} = 938\text{ lb}\qquad \textbf{Ans}$$

17-41. Block A weighs 50 lb and the platform weighs 10 lb. If $P = 100$ lb, determine the normal force exerted by block A on B. Neglect the weight of the pulleys and bars of the triangular frame.





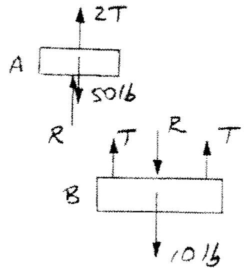
Assembly :

$+\uparrow \Sigma F_y = m(a_G)_y;\quad 100 - 60 = \frac{60}{32.2}a_G$

$a_G = 21.47\ \text{ft/s}^2$

Block A :

$+\uparrow \Sigma F_y = m(a_G)_y;\quad 2T + R - 50 = \frac{50}{32.2}(21.47)$



Block B :

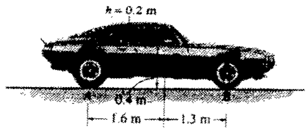
$+\uparrow \Sigma F_y = m(a_G)_y;\quad 2T - R - 10 = \frac{10}{32.2}(21.47)$

Solving,

$R = 33.3$ lb **Ans**

$T = 25$ lb

17-42. The 1.6-Mg car shown has been "raked" by increasing the height of its center of mass to $h = 0.2$ m. This was done by raising the springs on the rear axle. If the coefficient of kinetic friction between the rear wheels and the ground is $\mu_k = 0.3$, show that the car can accelerate slightly faster than its counterpart for which $h = 0$. Neglect the mass of the wheels and driver and assume the front wheels at B are free to roll while the rear wheels slip.



$\xrightarrow{+} \Sigma F_x = m(a_G)_x;\quad 0.3N_A = 1600a_G$

$+\uparrow \Sigma F_y = m(a_G)_y;\quad N_A + N_B - 1600(9.81) = 0$

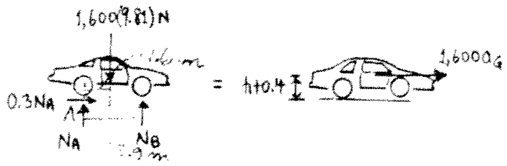
$\circlearrowleft + \Sigma M_A = \Sigma(M_k)_A;\quad -1600(9.81)(1.6) + N_B(2.9) = -1600a_G(h + 0.4)$

Set $h = 0.2$ m

$a_G = 1.41\ \text{m/s}^2$ **Ans**

$N_A = 7.50$ kN

$N_B = 8.19$ kN



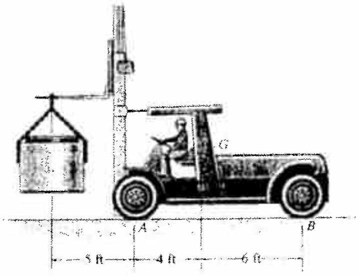
Set $h = 0$

$a_G = 1.38\ \text{m/s}^2$ **Ans**

$N_A = 7.34$ kN

$N_B = 8.36$ kN

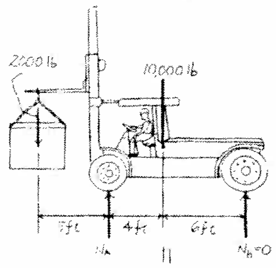
17-43. The forklift and operator have a combined weight of 10 000 lb and center of mass at G. If the forklift is used to lift the 2000-lb concrete pipe, determine the maximum vertical acceleration it can give to the pipe so that it does not tip forward on its front wheels.

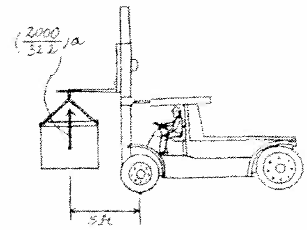


It is required that $N_B = 0$

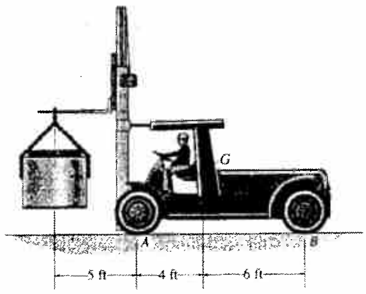
$$\circlearrowleft + \Sigma M_A = \Sigma(M_k)_A; \qquad 2000(5) - 10000(4) = -\left[\left(\frac{2000}{32.2}\right)a\right](5)$$

$$a = 96.6 \text{ ft/s}^2 \qquad \textbf{Ans}$$





***17-44.** The forklift and operator have a combined weight of 10 000 lb and center of mass at G. If the forklift is used to lift the 2000-lb concrete pipe, determine the normal reactions on each of its four wheels if the pipe is given an upward acceleration of 4 ft/s^2.

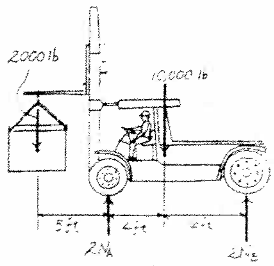


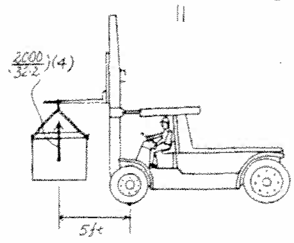
$$\circlearrowleft + \Sigma M_A = \Sigma(M_k)_A; \qquad 2000(5) + 2N_B(10) - 10000(4) = -\left[\left(\frac{2000}{32.2}\right)(4)\right](5)$$

$$N_B = 1437.89 \text{ lb} = 1.44 \text{ kip} \qquad \textbf{Ans}$$

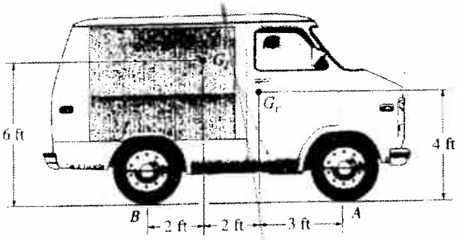
$$+\uparrow \Sigma F_y = m(a_G)_y; \qquad 2N_A + 2(1437.89) - 2000 - 10000 = \left(\frac{2000}{32.2}\right)(4)$$

$$N_A = 4686.34 \text{ lb} = 4.69 \text{ kip} \qquad \textbf{Ans}$$





17-45. The van has a weight of 4500 lb and center of gravity at G_r. It carries a fixed 800-lb load which has a center of gravity at G_l. If the van is traveling at 40 ft/s, determine the distance it skids before stopping. The brakes cause *all* the wheels to lock or skid. The coefficient of kinetic friction between the wheels and the pavement is $\mu_k = 0.3$. Compare this distance with that of the van being empty. Neglect the mass of the wheels.

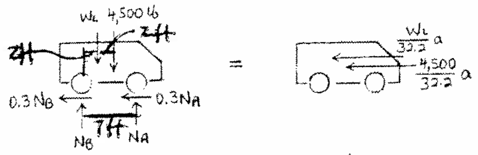


$$\overset{+}{\leftarrow} \Sigma F_x = m a_x; \qquad 0.3N_B + 0.3N_A = \frac{W_L}{32.2}a + \frac{4500}{32.2}a \qquad (1)$$

$$+\uparrow \Sigma F_y = m a_y; \qquad N_B + N_A - W_L - 4500 = 0 \qquad (2)$$

Set $W_L = 800$ lb in Eqs. (1) and (2)

$$N_A + N_B = 5300$$



$$a = 9.66 \text{ ft/s}^2$$

$$(\overset{+}{\rightarrow}) \qquad v^2 = v_0^2 + 2a_c(s - s_0)$$

$$0 = (40)^2 + 2(-9.66)(s - 0)$$

$s = 82.8$ ft **Ans**

For empty van $W_L = 0$ in Eqs. (1) and (2)

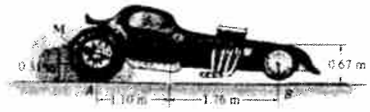
$$N_A + N_B = 4500$$

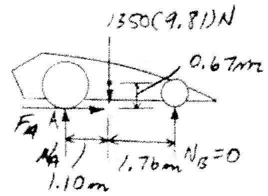
$$a = 9.66 \text{ ft/s}^2$$

Thus,

$s = 82.8$ ft as before **Ans**

17-46. The "muscle car" is designed to do a "wheeley," i.e., to be able to lift its front wheels off the ground in the manner shown when it accelerates. If the 1.35-Mg car has a center of mass at G, determine the minimum torque that must be developed at both rear wheels in order to do this. Also, what is the smallest necessary coefficient of static friction assuming the thick-walled rear wheels do not slip on the pavement? Neglect the mass of the wheels.





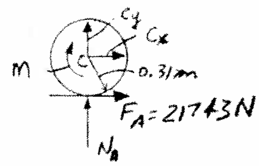
$\xrightarrow{+} \Sigma F_x = m(a_G)_x;\quad F_A = 1350a_G$

$+\uparrow \Sigma F_y = m(a_G)_y;\quad N_A - 1350(9.81) = 0$

$\curvearrowleft + \Sigma M_A = \Sigma(M_k)_A;\quad 1350(9.81)(1.10) = 1350a_G(0.67)$

Solving,

$a_G = 16.11\ \text{m/s}^2;\quad F_A = 21\,743\ \text{N};\quad N_A = 13\,244\ \text{N}$

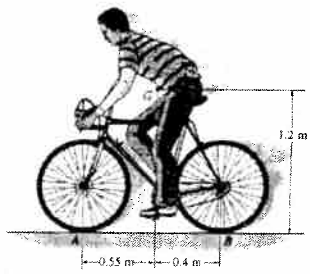


$\curvearrowleft + \Sigma M_C = 0;\quad 21\,743(0.31) - M = 0$

$M = 6.74\ \text{kN}\cdot\text{m}$ **Ans**

$\mu_{min} = \dfrac{F_A}{N_A} = \dfrac{21\,743}{13\,244} = 1.64$ **Ans**

17-47. The bicycle and rider have a mass of 80 kg with center of mass located at G. If the coefficient of kinetic friction at the rear tire is $\mu_B = 0.8$, determine the normal reactions at the tires A and B, and the deceleration of the rider, when the rear wheel locks for braking. What is the normal reaction at the rear wheel when the bicycle is traveling at constant velocity and the brakes are not applied? Neglect the mass of the wheels.

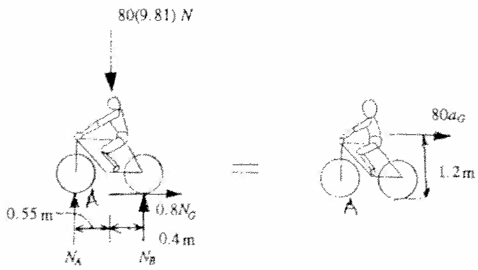


Deceleration :

$\xrightarrow{+} \Sigma F_x = m(a_G)_x;\quad 0.8N_B = 80a_G$

$+\uparrow \Sigma F_y = m(a_G)_y;\quad N_A + N_B - 80(9.81) = 0$

$\curvearrowleft + \Sigma M_A = \Sigma(M_k)_A;\quad -N_B(0.95) + 80(9.81)(0.55) = 80a_G(1.2)$



$a_G = 2.26\ \text{m/s}^2$ **Ans**

$N_B = 226\ \text{N}$ **Ans**

$N_A = 559\ \text{N}$ **Ans**

Equilibrium,

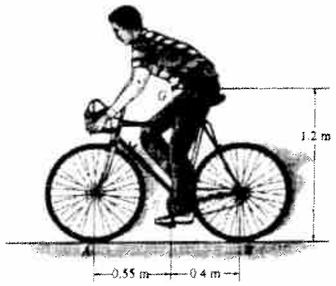
$+\uparrow \Sigma F_y = 0;\quad N_A + N_B - 80(9.81) = 0$

$\curvearrowleft + \Sigma M_A = 0;\quad -N_B(0.95) + 80(9.81)(0.55) = 0$

$N_A = 330\ \text{N}$

$N_B = 454\ \text{N}$ **Ans**

*17-48. The bicycle and rider have a mass of 80 kg with center of mass located at G. Determine the minimum coefficient of kinetic friction between the road and the wheels so that the rear wheel B starts to lift off the ground when the rider applies the brakes to the front wheel. Neglect the mass of the wheels.



$\xrightarrow{+} \Sigma F_x = m(a_G)_x;\quad \mu_k N_A = 80a_G$

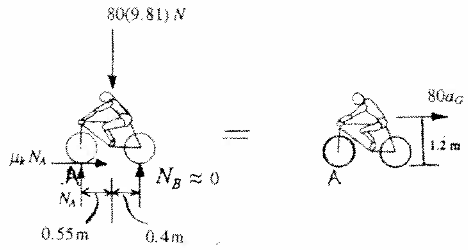
$+\uparrow \Sigma F_y = m(a_G)_y;\quad N_A - 80(9.81) = 0$

$\curvearrowleft + \Sigma M_A = \Sigma (M_k)_A;\quad 80(9.81)(0.55) = 80a_G(1.2)$

$N_A = 785$ N

$a_G = 4.50$ m/s^2

$\mu_k = 0.458$ **Ans**

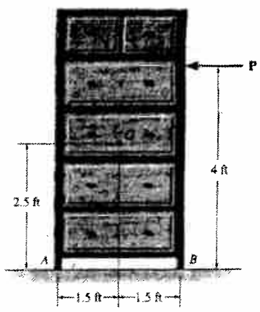


Also :

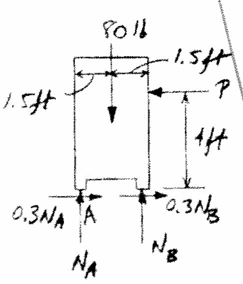
$\curvearrowleft + \Sigma M_G = 0;\quad N_A(0.55) - \mu_k N_A(1.2) = 0$

$\mu_k = 0.458$ **Ans**

17-49. The dresser has a weight of 80 lb and is pushed along the floor. If the coefficient of static friction at A and B is $\mu_s = 0.3$ and the coefficient of kinetic friction is $\mu_k = 0.2$, determine the smallest horizontal force P needed to cause motion. If this force is increased slightly, determine the acceleration of the dresser. Also, what are the normal reactions at A and B when it begins to move?



For slipping :



$\xrightarrow{+} \Sigma F_x = 0;\quad -P + 0.3(N_A + N_B) = 0$

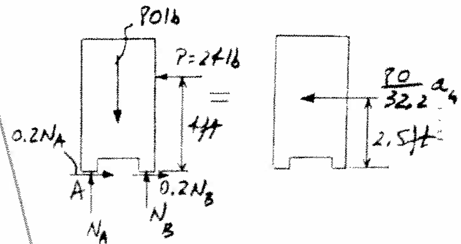
$+\uparrow \Sigma F_y = 0;\quad N_A + N_B - 80 = 0$

$P = 24$ lb **Ans**

For tipping $N_B = 0$, $N_A = 80$ lb.

$\curvearrowleft + \Sigma M_A = 0;\quad P(4) - 80(1.5) = 0$

$P = 30 \text{ lb} > 24 \text{ lb}$



Dresser slips.

$\xleftarrow{+} \Sigma F_x = m(a_G)_x;\quad 24 - 0.2N_A - 0.2N_B = \left(\frac{80}{32.2}\right)a_G$

$+\uparrow \Sigma F_y = 0;\quad N_A + N_B - 80 = 0$

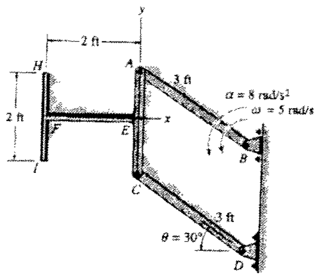
$\curvearrowleft + \Sigma M_A = \Sigma (M_k)_A;\quad 24(4) + N_B(3) - 80(1.5) = \left(\frac{80}{32.2}\right)a_G(2.5)$

$a_G = 3.22$ ft/s^2 **Ans**

$N_B = 14.7$ lb **Ans**

$N_A = 65.3$ lb **Ans**

*17-52. The two 3-lb rods EF and HI are fixed (welded) to the link AC at E. Determine the normal force N_E, shear force V_E, and moment M_E, which the bar AC exerts on FE at E if at the instant $\theta = 30°$ link AB has an angular velocity $\omega = 5$ rad/s and an angular acceleration $\alpha = 8$ rad/s^2 as shown.



Curvilinear translation :

$(a_G)_n = (5)^2(3) = 75$ ft/s^2 $\measuredangle 30°$

$(a_G)_t = 8(3) = 24$ ft/s^2 $\measuredangle 30°$

$\bar{x} = \dfrac{\Sigma \tilde{x} m}{\Sigma m} = \dfrac{1(3) + 2(3)}{6} = 1.5$ ft

$\xrightarrow{+} \Sigma F_x = m(a_G)_x$; $\quad N_E = \left(\dfrac{6}{32.2}\right)(75)\cos 30° - \left(\dfrac{6}{32.2}\right)(24)\sin 30°$

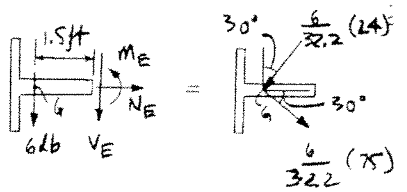
$+\downarrow \Sigma F_y = m(a_G)_y$; $\quad V_E + 6 = \left(\dfrac{6}{32.2}\right)(24)\cos 30° + \left(\dfrac{6}{32.2}\right)(75)\sin 30°$

$\circlearrowleft + \Sigma M_G = 0$; $\quad M_E - V_E(1.5) = 0$

$N_E = 9.87$ lb **Ans**

$V_E = 4.86$ lb **Ans**

$M_E = 7.29$ lb · ft **Ans**



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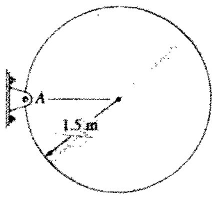
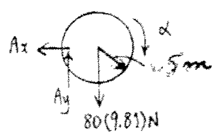
17-53. The 80-kg disk is supported by a pin at A. If it is released from rest from the position shown, determine the initial horizontal and vertical components of reaction at the pin.



$\xleftarrow{+} \Sigma F_x = m(a_G)_x$; $\quad A_x = 0$ **Ans**

$+\uparrow \Sigma F_y = m(a_G)_y$; $\quad A_y - 80(9.81) = -80(1.5)(\alpha)$

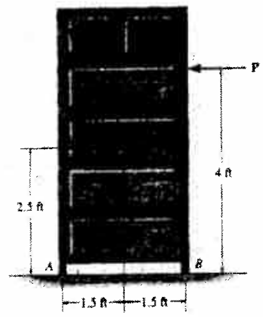
$\circlearrowleft + \Sigma M_A = I_A \alpha$; $\quad 80(9.81)(1.5) = [\frac{3}{2}(80)(1.5)^2]\alpha$



$\alpha = 4.36$ rad/s^2

$A_y = 262$ N **Ans**

17-50. The dresser has a weight of 80 lb and is pushed along the floor. If the coefficient of static friction at A and B is $\mu_s = 0.3$ and the coefficient of kinetic friction is $\mu_k = 0.2$, determine the maximum horizontal force P that can be applied without causing the dresser to tip over.



When force P is applied, dresser will slide before tipping.
See Prob. 17 – 45.

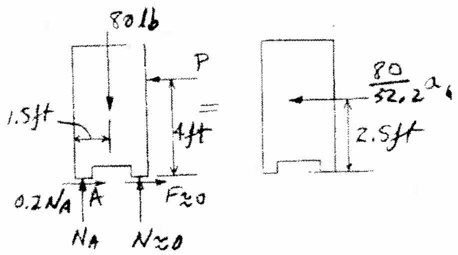
$$+\uparrow \Sigma F_y = 0; \qquad N_A - 80 = 0$$

$$\overset{+}{\leftarrow} \Sigma F_x = m(a_G)_x; \qquad P - 0.2N_A = \left(\frac{80}{32.2}\right)a_G$$

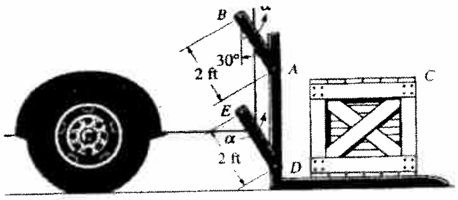
$$\circlearrowleft + \Sigma M_A = \Sigma(M_k)_A; \qquad P(4) - 80(1.5) = \left(\frac{80}{32.2}\right)a_G(2.5)$$

$P = 53.3$ lb **Ans**

$a_G = 15.0$ ft/s^2



17-51. The crate C has a weight of 150 lb and rests on the truck elevator for which the coefficient of static friction is $\mu_s = 0.4$. Determine the largest initial angular acceleration α, starting from rest, which the parallel links AB and DE can have without causing the crate to slip. No tipping occurs.



$$\overset{+}{\rightarrow} \Sigma F_x = ma_x; \qquad 0.4N_C = \frac{150}{32.2}(a)\cos 30°$$

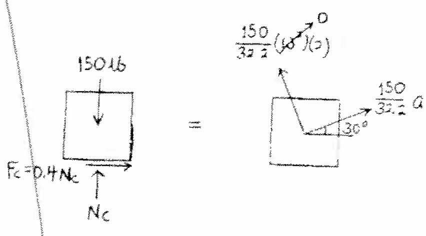
$$+\uparrow \Sigma F_y = ma_y; \qquad N_C - 150 = \frac{150}{32.2}(a)\sin 30°$$

$N_C = 195.0$ lb

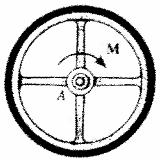
$a = 19.34$ ft/s^2

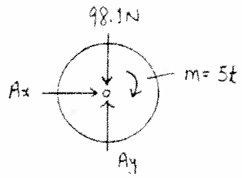
$19.34 = 2\alpha$

$\alpha = 9.67$ rad/s^2 **Ans**



17-54. The 10-kg wheel has a radius of gyration $k_A = 200$ mm. If the wheel is subjected to a moment $M = (5t)$ N·m, where t is in seconds, determine its angular velocity when $t = 3$ s starting from rest. Also, compute the reactions which the fixed pin A exerts on the wheel during the motion.





$$\xrightarrow{+} \Sigma F_x = m(a_G)_x; \qquad A_x = 0$$

$$+\uparrow \Sigma F_y = m(a_G)_y; \qquad A_y - 10(9.81) = 0$$

$$\curvearrowright + \Sigma M_A = I_A\,\alpha; \qquad 5t = 10(0.2)^2\alpha$$

$$\alpha = \frac{d\omega}{dt} = 12.5t$$

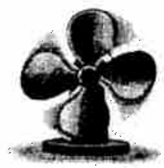
$$\omega = \int_0^3 12.5t\,dt = \frac{12.5}{2}(3)^2$$

$\omega = 56.2$ rad/s **Ans**

$A_x = 0$ **Ans**

$A_y = 98.1$ N **Ans**

17-55. The fan blade has a mass of 2 kg and a moment of inertia $I_O = 0.18$ kg·m^2 about an axis passing through its center O. If it is subjected to a moment of $M = 3(1 - e^{-0.2t})$ N·m, where t is in seconds, determine its angular velocity when $t = 4$ s starting from rest.



$$\curvearrowleft + \Sigma M_O = I_O\,\alpha; \qquad 3\left(1 - e^{-0.2t}\right) = 0.18\alpha$$

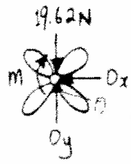
$$\alpha = 16.67\left(1 - e^{-0.2t}\right)$$

$$d\omega = \alpha\,dt$$

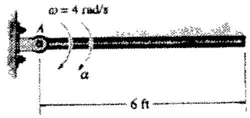
$$\int_0^{\omega} d\omega = \int_0^4 16.67\left(1 - e^{-0.2t}\right) dt$$

$$\omega = 16.67\left[t + \frac{1}{0.2}e^{-0.2t}\right]_0^4$$

$\omega = 20.8$ rad/s **Ans**



*17-56. The 10-lb rod is pin connected to its support at A and has an angular velocity $\omega = 4$ rad/s when it is in the horizontal position shown. Determine its angular acceleration and the horizontal and vertical components of reaction which the pin exerts on the rod at this instant.

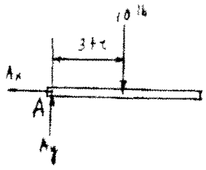


Equations of motion :

$\overset{+}{\leftarrow}\Sigma F_n = m\omega^2 r_G;\quad A_x = \left(\frac{10}{32.2}\right)(4)^2(3)\quad A_x = 14.9\text{ lb}$ **Ans**

$\circlearrowleft + \;\Sigma M_A = I_A\alpha;\quad 10(3) = \frac{1}{3}\left(\frac{10}{32.2}\right)(6)^2\alpha\quad \alpha = 8.05\text{ rad/s}^2$ **Ans**

$+\downarrow\Sigma F_t = m\alpha r_G;\quad 10 - A_y = \left(\frac{10}{32.2}\right)(8.05)(3)\quad A_y = 2.50\text{ lb}$ **Ans**



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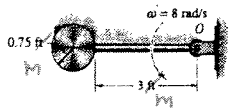
17-57. The pendulum consists of a 15-lb disk and a 10-lb slender rod. Determine the horizontal and vertical components of reaction that the pin O exerts on the rod just as it passes the horizontal position, at which time its angular velocity is $\omega = 8$ rad/s.



$+\uparrow\Sigma F_y = m(a_G)_y;\quad O_y - 15 - 10 = -\left(\frac{15}{\cancel{32.2}}\right)[3.75\alpha] - \left(\frac{10}{\cancel{32.2}}\right)[1.5\alpha]$ 9.81 9.81

$\overset{+}{\rightarrow}\Sigma F_x = m(a_G)_x;\quad O_x = \left(\frac{15}{\cancel{32.2}}\right)(3.75)(8)^2 + \left(\frac{10}{\cancel{32.2}}\right)(1.5)(8)^2$ 9.81 9.81

$\circlearrowleft + \Sigma M_O = \Sigma(M_k)_O:\quad 15(3.75) + 10(1.5) = \left[\frac{1}{2}\left(\frac{15}{\cancel{32.2}}\right)(0.75)^2\right]\alpha + \left(\frac{15}{\cancel{32.2}}\right)(3.75)\alpha(3.75)$ 9.81 9.81

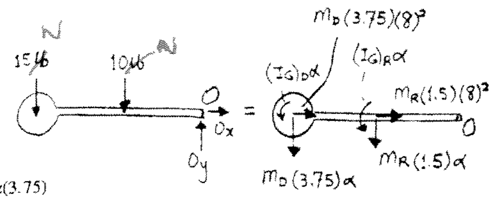
$+\left[\frac{1}{12}\left(\frac{10}{\cancel{32.2}}\right)(3)^2\right]\alpha + \left(\frac{10}{\cancel{32.2}}\right)(1.5)\alpha(1.5)$ 9.81 9.81

$\alpha = \cancel{9.36\text{ rad/s}^2}$ 2.85 rad/s^2

466 N

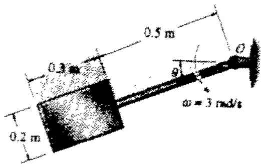
$O_x = \cancel{142\text{ lb}} \rightarrow$ **Ans**

$O_y = 4.29\ \cancel{\text{lb}}\ \text{N} \uparrow$ **Ans**



33

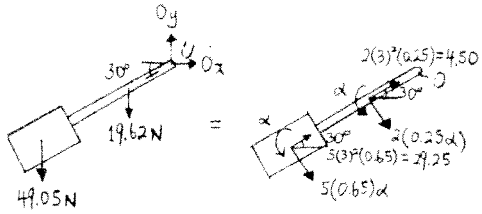
17-58. The pendulum consists of a uniform 5-kg plate and a 2-kg slender rod. Determine the horizontal and vertical components of reaction that the pin O exerts on the rod at the instant $\theta = 30°$, at which time its angular velocity is $\omega = 3$ rad/s.



$$I_O = \frac{1}{12}(5)\left[(0.3)^2 + (0.2)^2\right] + 5(0.65)^2 + \frac{1}{3}(2)(0.5)^2 = 2.333 \text{ kg} \cdot \text{m}^2$$

$\circlearrowleft + \Sigma M_O = I_O\alpha;$ $\quad 19.62(0.25\cos 30°) + 49.05(0.65\cos 30°) = 2.333\alpha$

$\alpha = 13.65 \text{ rad/s}^2$



$\xrightarrow{+} \Sigma F_x = m(a_G)_x;$ $\quad O_x = 4.50\cos 30° + 2(0.25)(13.65)\sin 30° + 29.25\cos 30°$

$+5(0.65)(13.65)\sin 30°$

$O_x = 54.8$ N **Ans**

$+\uparrow \Sigma F_y = m(a_G)_y;$ $\quad O_y - 49.05 - 19.62 = (29.25 + 4.50)\sin 30°$

$-[5(0.65)(13.65) + 2(0.25)(13.65)]\cos 30°$

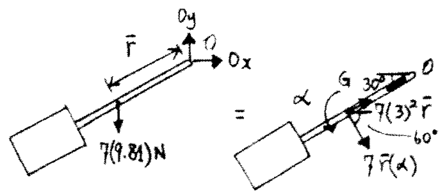
$O_y = 41.2$ N **Ans**

Also, the problem can be solved as follows :

$$\bar{r} = \frac{\Sigma \bar{r} m}{\Sigma m} = \frac{(0.25)(2) + 0.65(5)}{7} = 0.5357 \text{ m}$$

$+\Sigma M_0 = I_0\alpha;$ $\quad 7(9.81)(0.5357\cos 30°) = 2.333\alpha$

$\alpha = 13.65 \text{ rad/s}^2$



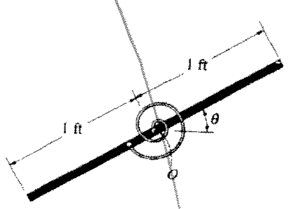
$\xrightarrow{+} \Sigma F_x = m(a_G)_x;$ $\quad O_x = 7(3)^2(0.5357\cos 30°) + 7(0.5357)(13.65)\cos 60°$

$O_x = 54.8$ N **Ans**

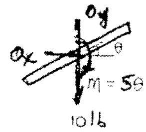
$+\uparrow \Sigma F_y = m(a_G)_y;$ $\quad O_y - 7(9.81) = 7(3)^2(0.5357)(\sin 30°) - 7(0.5357)(13.65)\sin 60°$

$O_y = 41.2$ N **Ans**

17-59. The 10-lb bar is pinned at its center O and connected to a torsional spring. The spring has a stiffness $k = 5\ \text{lb}\cdot\text{ft/rad}$, so that the torque developed is $M = (5\theta)\ \text{lb}\cdot\text{ft}$, where θ is in radians. If the bar is released from rest when it is vertical at $\theta = 90°$, determine its angular velocity at the instant $\theta = 0°$.



$$\circlearrowleft + \Sigma M_O = I_O\alpha; \quad -5\theta = [\frac{1}{12}(\frac{10}{32.2})(2)^2]\alpha$$



$$-48.3\ \theta = \alpha$$

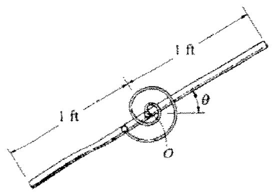
$$\alpha\, d\theta = \omega\, d\omega$$

$$-\int_{\frac{\pi}{2}}^{0} 48.3\ \theta\, d\theta = \int_0^{\omega} \omega\, d\omega$$

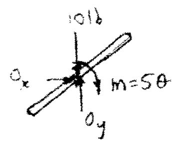
$$\frac{48.3}{2}(\frac{\pi}{2})^2 = \frac{1}{2}\omega^2$$

$\omega = 10.9\ \text{rad/s}$ **Ans**

***17-60.** The 10-lb bar is pinned at its center O and connected to a torsional spring. The spring has a stiffness $k = 5\ \text{lb}\cdot\text{ft/rad}$, so that the torque developed is $M = (5\theta)\ \text{lb}\cdot\text{ft}$, where θ is in radians. If the bar is released from rest when it is vertical at $\theta = 90°$, determine its angular velocity at the instant $\theta = 45°$.



$$\circlearrowleft + \Sigma M_O = I_O\alpha; \quad 5\theta = [\frac{1}{12}(\frac{10}{32.2})(2)^2]\alpha$$



$$\alpha = -48.3\theta$$

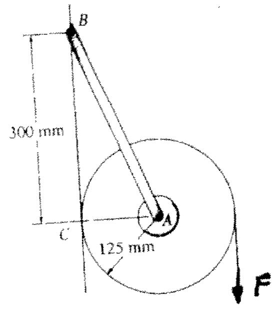
$$\alpha\, d\theta = \omega\, d\omega$$

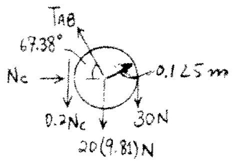
$$-\int_{\frac{\pi}{2}}^{\frac{\pi}{4}} 48.3\theta\, d\theta = \int_0^{\omega} \omega\, d\omega$$

$$-24.15\left((\frac{\pi}{4})^2 - (\frac{\pi}{2})^2\right) = \frac{1}{2}\omega^2$$

$\omega = 9.45\ \text{rad/s}$ **Ans**

17-61. 34 The 20-kg roll of paper has a radius of gyration $k_A = 90$ mm about an axis passing through point A. It is pin-supported at both ends by two brackets AB. If the roll rests against a wall for which the coefficient of kinetic friction is $\mu_k = 0.2$ and a vertical force $F = 30$ N is applied to the end of the paper, determine the angular acceleration of the roll as the paper unrolls.





$$\xrightarrow{+} \Sigma F_x = m(a_G)_x; \qquad N_C - T_{AB}\cos 67.38^\circ = 0$$

$$+\uparrow \Sigma F_y = m(a_G)_y; \qquad T_{AB}\sin 67.38^\circ - 0.2N_C - 20(9.81) - 30 = 0$$

$$\circlearrowleft + \Sigma M_A = I_A\,\alpha; \qquad -0.2N_C(0.125) + 30(0.125) = 20(0.09)^2\alpha$$

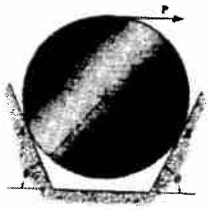
Solving;

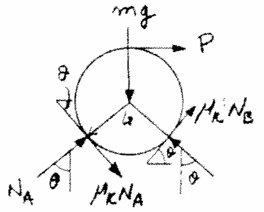
$N_C = 103$ N

$T_{AB} = 267$ N

$\alpha = 7.28\ \text{rad/s}^2$ **Ans**

17-62. The cylinder has a radius r and mass m and rests in the trough for which the coefficient of kinetic friction at A and B is μ_k. If a horizontal force **P** is applied to the cylinder, determine the cylinder's angular acceleration when it begins to spin.





$\xrightarrow{+} \Sigma F_x = m(a_G)_x;\quad P + N_A \sin\theta + \mu_k N_A \cos\theta + \mu_k N_B \cos\theta - N_B \sin\theta = 0$

$+\uparrow \Sigma F_y = m(a_G)_y;\quad N_A \cos\theta - \mu_k N_A \sin\theta + N_B \cos\theta + \mu_k N_B \sin\theta - mg = 0$

$\curvearrowleft + \Sigma M_G = I_G\alpha;\quad \mu_k N_A (r) + \mu_k N_B (r) - P(r) = -\left(\frac{1}{2}mr^2\right)\alpha$

$$P - (N_B - N_A)\sin\theta + \mu_k \cos\theta(N_A + N_B) = 0 \qquad (2)$$

$$(N_A + N_B)\cos\theta + \mu_k \sin\theta(N_B - N_A) = mg \qquad (1)$$

$$\mu_k (N_A + N_B) = P - \frac{1}{2}mr\alpha \qquad (3)$$

From Eqs. (1) and (2),

$$(N_A + N_B)\cos\theta + \mu_k\left[P + \mu_k \cos\theta(N_A + N_B)\right] = mg$$

or,

$$(N_A + N_B)\left(\cos\theta + \mu_k^2 2\cos\theta\right) = mg - \mu_k P$$

$$(N_A + N_B) = \frac{mg - \mu_k P}{\cos\theta(1 + \mu_k^2)}$$

From Eq. (3),

$$\mu_k\left(\frac{mg - \mu_k P}{\cos\theta(1 + \mu_k^2)}\right) = P - \frac{1}{2}mr\alpha$$

$$\alpha = -\frac{2\mu_k}{mr}\left(\frac{mg - \mu_k P}{\cos\theta(1 + \mu_k^2)}\right) + \frac{2P}{mr} \qquad \textbf{Ans}$$

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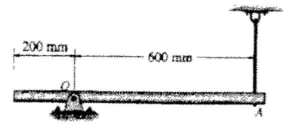
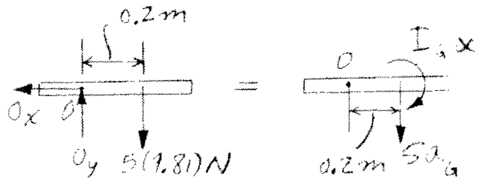
17-63. The uniform slender rod has a mass of 5 kg. If the cord at A is cut, determine the reaction at the pin O, (a) when the rod is still in the horizontal position, and (b) when the rod swings to the vertical position.



(a) $\omega = 0, \quad (a_G)_n = 0, \quad (a_G)_t = 0.2\alpha$

$\circlearrowleft + \Sigma M_O = I_O\alpha; \quad (0.2)(5)(9.81) = \left[\frac{1}{12}(5)(0.8)^2 + 5(0.2)^2\right]\alpha$

$$\alpha = 21.02 \text{ rad/s}^2$$



$\xrightarrow{+} \Sigma F_n = m(a_G)_n; \quad O_x = 0$

$+\uparrow \Sigma F_t = m(a_G)_t; \quad O_y - 5(9.81) = -5(0.2\alpha)$

Thus, $\quad O_y = 28.0$ N

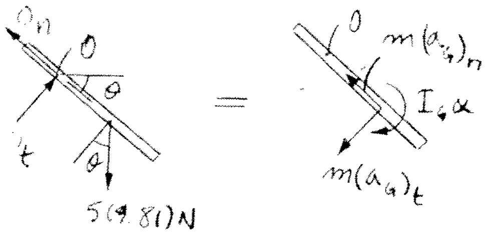
And

$$F_O = \sqrt{(0)^2 + (28.0)^2} = 28.0 \text{ N} \qquad \textbf{Ans}$$

(b)

$\circlearrowleft + \Sigma M_O = I_O\alpha; \quad 5(9.81)(0.2)\cos\theta = \left[\frac{1}{12}(5)(0.8)^2 + 5(0.2)^2\right]\alpha$

$$\alpha = 21.02\cos\theta \qquad (1)$$



$\nwarrow + \Sigma F_n = m(a_G)_n; \quad O_n - 5(9.81)\sin\theta = 5(\omega^2)(0.2) \qquad (2)$

$\swarrow + \Sigma F_t = m(a_G)_t; \quad -O_t + 5(9.81)\cos\theta = 5(\alpha)(0.2) \qquad (3)$

$\omega\, d\omega = \alpha\, d\theta$

$\int_0^{\omega} \omega\, d\omega = \int_0^{90^\circ} 21.02\cos\theta\, d\theta$

$\frac{1}{2}\omega^2 = 21.02\sin\theta\Big|_0^{90^\circ}$

$\omega = 6.484$ rad/s

Substituting into Eq. (2) and solving Eqs. (1) – (3) with $\theta = 90^\circ$ yields

$O_n = 91.09 \text{ N} \uparrow$

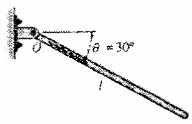
$O_t = 0$

$\alpha = 0$

Thus,

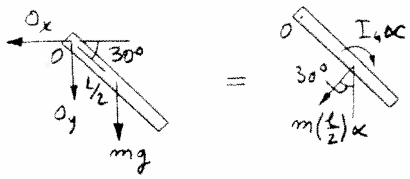
$F_O = \sqrt{(0)^2 + (91.1)^2} = 91.1 \text{ N} \qquad$ **Ans**

***17-64.** The bar has a mass m and length l. If it is released from rest from the position $\theta = 30°$, determine its angular acceleration and the horizontal and vertical components of reaction at the pin O.



$\curvearrowleft + \Sigma M_O = I_O\alpha; \qquad (mg)\left(\frac{l}{2}\right)\cos 30° = \frac{1}{3}ml^2\alpha$

$$\alpha = \frac{1.299g}{l} = \frac{1.30g}{l} \qquad \textbf{Ans}$$



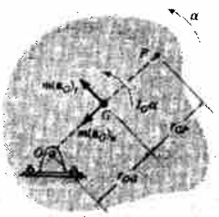
$\overset{+}{\leftarrow} \Sigma F_x = m(a_G)_x; \qquad O_x = m\left(\frac{l}{2}\right)\left(\frac{1.299g}{l}\right)\sin 30°$

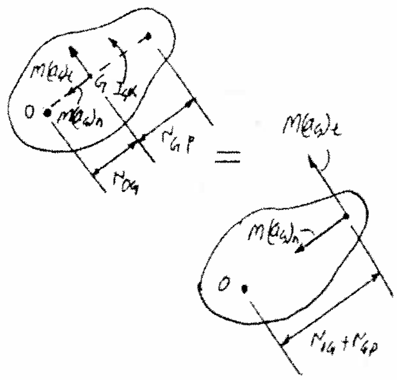
$$O_x = 0.325mg \qquad \textbf{Ans}$$

$+\uparrow \Sigma F_y = m(a_G)_y; \qquad O_y - mg = -m\left(\frac{l}{2}\right)\left(\frac{1.299g}{l}\right)\cos 30°$

$$O_y = 0.438mg \qquad \textbf{Ans}$$

17-65. The kinetic diagram representing the general rotational motion of a rigid body about a fixed axis at O is shown in the figure. Show that $I_G\alpha$ may be eliminated by moving the vectors $m(\mathbf{a}_G)_t$ and $m(\mathbf{a}_G)_n$ to point P, located a distance $r_{GP} = k_G^2/r_{OG}$ from the center of mass G of the body. Here k_G represents the radius of gyration of the body about G. The point P is called the *center of percussion* of the body.





$$m(a_G)_t r_{OG} + I_G\alpha = m(a_G)_t r_{OG} + (mk_G^2)\alpha$$

However, $\quad k_G^2 = r_{OG}r_{GP}$ and $\alpha = \dfrac{(a_G)_t}{r_{OG}}$

$$m(a_G)_t r_{OG} + I_G\alpha = m(a_G)_t r_{OG} + (mr_{OG}r_{GP})\left[\frac{(a_G)_t}{r_{OG}}\right]$$

$$= m(a_G)_t(r_{OG} + r_{GP}) \qquad \textbf{Q.E.D.}$$

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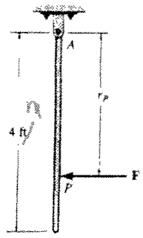
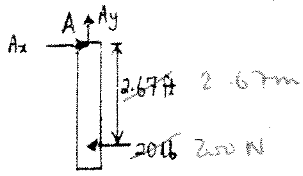
17-66. Determine the position r_P of the center of percussion P of the 10-lb slender bar. (See Prob. 17-65.) What is the horizontal force A_x at the pin when the bar is struck at P with a force of $F = 20$ lb? 100 N 200 N



Using the result of Prob 17 - 65

$$r_{GP} = \frac{k_G^2}{r_{AG}} = \frac{\left[\sqrt{\frac{1}{12}\left(\frac{ml^2}{m}\right)}\right]^2}{\frac{l}{2}} = \frac{1}{6}l$$



Thus,

$$r_P = \frac{1}{6}l + \frac{1}{2}l = \frac{2}{3}l = \frac{2}{3}(4) = 2.67\ \cancel{\text{ft}}\ \text{m} \qquad \textbf{Ans}$$

$$\circlearrowleft + \Sigma M_A = I_A\,\alpha; \qquad \overset{200}{\cancel{20}}(2.667) = \left[\frac{1}{3}\left(\frac{\overset{100}{\cancel{10}}}{\underset{9.81}{\cancel{32.2}}}\right)(4)^2\right]\alpha$$

$$\alpha = 32.\cancel{2\ \text{rad/s}^2} \quad 9.81\ \text{rad/s}^2$$

$$(a_G)_t = 2(\overset{9.81}{\cancel{32.2}}) = \cancel{64.4\ \text{ft/s}^2} \quad 19.62\ \text{m/s}^2$$

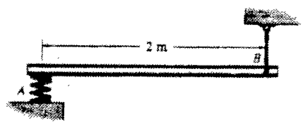
$$\overset{+}{\leftarrow} \Sigma F_x = m(a_G)_t; \qquad -A_x + \overset{200}{\cancel{20}} = \left(\frac{\overset{100}{\cancel{10}}}{\underset{9.81}{\cancel{32.2}}}\right)(\cancel{64.4})\ 19.62$$

$$A_x = 0 \qquad \textbf{Ans}$$

✓

37 40

17-67. The 4-kg slender rod is supported horizontally by a spring at A and a cord at B. Determine the angular acceleration of the rod and the acceleration of the rod's mass center at the instant the cord at B is cut. *Hint:* The stiffness of the spring is not needed for the calculation.



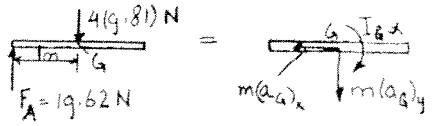
Since the deflection of the spring is unchanged at the instant the cord is cut, the reaction at A is

$$F_A = \frac{4}{2}(9.81) = 19.62\ \text{N}$$

$$\overset{+}{\leftarrow} \Sigma F_x = m(a_G)_x; \qquad 0 = 4(a_G)_x$$

$$+\downarrow \Sigma F_y = m(a_G)_y; \qquad 4(9.81) - 19.62 = 4(a_G)_y$$

$$\circlearrowleft + \Sigma M_G = I_G\alpha; \qquad (19.62)(1) = \left[\frac{1}{12}(4)(2)^2\right]\alpha$$



Solving :

$(a_G)_x = 0$

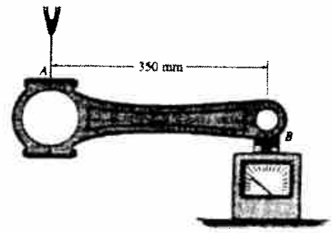
$(a_G)_y = 4.905\ \text{m/s}^2$

$\alpha = 14.7\ \text{rad/s}^2$ **Ans**

Thus,

$(a_G) = 4.90\ \text{m/s}^2$ **Ans**

*17-68. In order to experimentally determine the moment of inertia I_G of a 4-kg connecting rod, the rod is suspended horizontally at A by a cord and at B by a bearing and piezoelectric sensor, an instrument used for measuring force. Under these equilibrium conditions, the force at B is measured as 14.6 N. If, at the instant the cord is released, the reaction at B is measured as 9.3 N, determine the value of I_G. The support at B does not move when the measurement is taken. For the calculation, the horizontal location of G must be determined.



The location of G is :

$\circlearrowleft + \Sigma M_A = 0;\quad 14.6(0.35) - 4(9.81)(x) = 0$

$x = 0.1302$ m

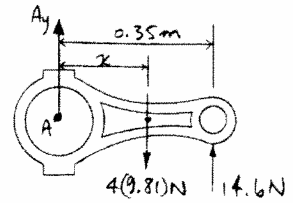
$+\downarrow \Sigma F_y = m(a_G)_y;\quad 4(9.81) - 9.3 = 4a_G$

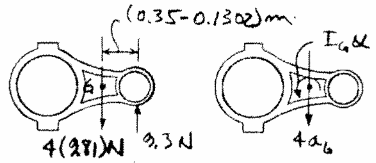
$a_G = 7.485\ \text{m/s}^2$

Since $a_G = (0.350 - 0.1302)\alpha,\quad \alpha = 34.06\ \text{rad/s}^2$

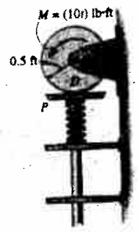
$\circlearrowleft + \Sigma M_G = I_G\alpha;\quad 9.3(0.350 - 0.1302) = I_G(34.06)$

$I_G = 0.0600\ \text{kg}\cdot\text{m}^2$ **Ans**





17-69. The 10-lb disk D is subjected to a counterclockwise moment of $M = (10t)$ lb·ft, where t is in seconds. Determine the angular velocity of the disk 2 s after the moment is applied. Due to the spring the plate P exerts a constant force of 100 lb on the disk. The coefficients of static and kinetic friction between the disk and the plate are $\mu_s = 0.3$ and $\mu_k = 0.2$, respectively. *Hint:* First find the time needed to start the disk rotating.

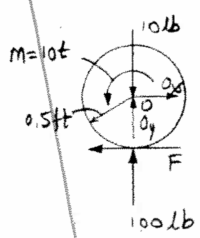


Determine time required to start disk in motion.

$F = 0.3(100) = 30$ lb

$\circlearrowleft + \Sigma M_O = 0;\quad 10t - 30(0.5) = 0$

$t = 1.5$ s



Thus,

$F = 0.2(100) = 20$ lb

$\circlearrowleft + \Sigma M_O = I_O\alpha;\quad 10t - 20(0.5) = \left[\left(\frac{1}{2}\right)\left(\frac{10}{32.2}\right)(0.5)^2\right]\alpha$

$\alpha = 257.6(t - 1)$

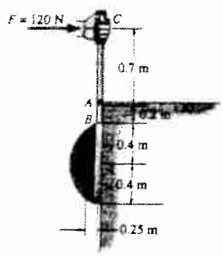
Since $\alpha = \dfrac{d\omega}{dt}$,

$\int_0^\omega d\omega = \int_{1.5}^{2} 257.6(t-1)\,dt$

$\omega = 257.6\left(\frac{t^2}{2} - t\right)\Big|_{1.5}^{2}$

$\omega = 96.6$ rad/s **Ans**

17-70. The furnace cover has a mass of 20 kg and a radius of gyration $k_G = 0.25$ m about its mass center G. If an operator applies a force $F = 120$ N to the handle in order to open the cover, determine the cover's initial angular acceleration and the horizontal and vertical components of reaction which the pin at A exerts on the cover at the instant the cover begins to open. Neglect the mass of the handle BAC in the calculation.



$\overset{+}{\leftarrow} \Sigma F_x = m(a_G)_x;\quad A_x - 120 = 20(0.65)\alpha\cos 22.62°$

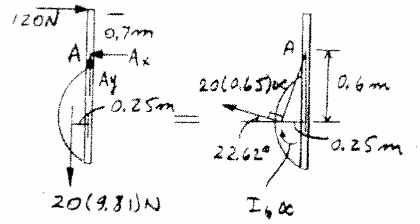
$+\uparrow \Sigma F_y = m(a_G)_y;\quad A_y - 20(9.81) = 20(0.65)\alpha\sin 22.62°$

$\circlearrowleft + \Sigma M_A = \Sigma(M_k)_A;\quad 120(0.7) - 20(9.81)(0.25) = 20(0.25)^2\alpha + 20(0.65)\alpha(0.65)$

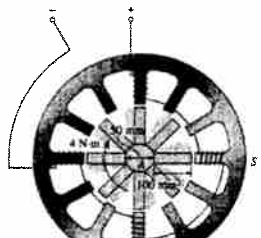
$\alpha = 3.60 \text{ rad/s}^2$ **Ans**

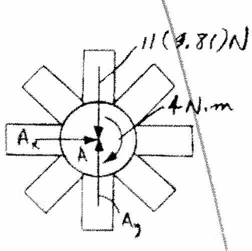
$A_x = 163$ N **Ans**

$A_y = 214$ N **Ans**



17-71. The variable-resistance motor is often used for appliances, pumps, and blowers. By applying a current through the stator S, an electromagnetic field is created that "pulls in" the nearest rotor poles. The result of this is to create a torque of 4 N·m about the bearing A. If the rotor is made from iron and has a 3-kg cylindrical core of 50-mm diameter and eight extended slender rods, each having a mass of 1 kg and 100-mm length, determine its angular velocity in 5 seconds starting from rest.





$I_A = \frac{1}{2}(3)(0.025)^2 + 8\left[\frac{1}{12}(1)(0.1)^2 + (1)(0.075)^2\right] = 0.052604 \text{ kg}\cdot\text{m}^2$

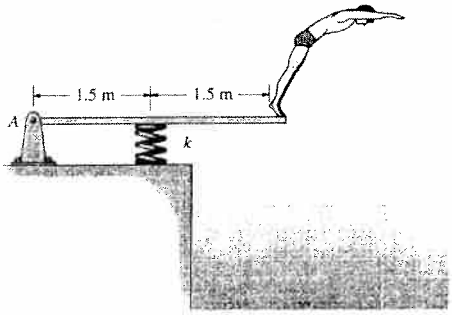
$\circlearrowleft + \Sigma M_A = I_A\,\alpha;\quad 4 = 0.052604\alpha$

$\alpha = 76.04 \text{ rad/s}^2$

$\circlearrowleft + \omega = \omega_0 + \alpha_c t$

$\omega = 0 + 76.04(5) = 380$ rad/s **Ans**

***17-72.** Determine the angular acceleration of the 25-kg diving board and the horizontal and vertical components of reaction at the pin A the instant the man jumps off. Assume that the board is uniform and rigid, and that at the instant he jumps off the spring is compressed a maximum amount of 200 mm, $\omega = 0$, and the board is horizontal. Take $k = 7$ kN/m.



$\curvearrowleft + \sum M_A = I_A\alpha;\quad 1.5(1400 - 245.25) = \left[\frac{1}{3}(25)(3)^2\right]\alpha$

$+\uparrow \sum F_t = m(a_G)_t;\quad 1400 - 245.25 - A_y = 25(1.5\alpha)$

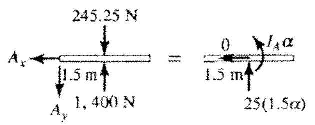
$\overset{+}{\leftarrow} \sum F_n = m(a_G)_n;\quad A_x = 0$

Solving,

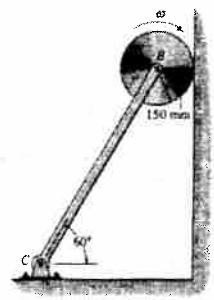
$A_x = 0$ **Ans**

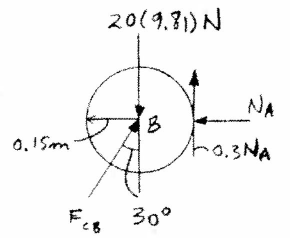
$A_y = 289$ N **Ans**

$\alpha = 23.1$ rad/s^2 **Ans**



17-73. The disk has a mass of 20 kg and is originally spinning at the end of the strut with an angular velocity of $\omega = 60$ rad/s. If it is then placed against the wall, for which the coefficient of kinetic friction is $\mu_k = 0.3$, determine the time required for the motion to stop. What is the force in strut BC during this time?





$\xrightarrow{+} \Sigma F_x = m(a_G)_x;\quad F_{CB}\sin 30^\circ - N_A = 0$

$+\uparrow \Sigma F_y = m(a_G)_y;\quad F_{CB}\cos 30^\circ - 20(9.81) + 0.3N_A = 0$

$\curvearrowleft + \Sigma M_B = I_B\,\alpha;\quad 0.3N_A\,(0.15) = \left[\frac{1}{2}(20)(0.15)^2\right]\alpha$

$N_A = 96.6$ N

$F_{CB} = 193$ N **Ans**

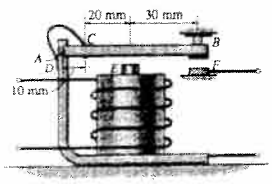
$\alpha = 19.3$ rad/s^2

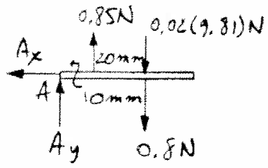
$\curvearrowleft + \;\omega = \omega_0 + \alpha_c t$

$0 = 60 + (-19.3)t$

$t = 3.11$ s **Ans**

17-74. The relay switch consists of an electromagnet E and a 20-g armature AB (slender bar) which is pinned at A and lies in the vertical plane. When the current is turned off, the armature is held open against the smooth stop at B by the spring CD, which exerts an upward vertical force $F_s = 0.85$ N on the armature at C. When the current is turned on, the electromagnet attracts the armature at E with a vertical force $F = 0.8$ N. Determine the initial angular acceleration of the armature when the contact BF begins to close.

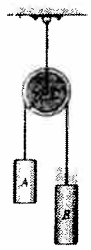




$$\circlearrowleft + \Sigma M_A = I_A\,\alpha; \quad \left[(0.02)(9.81) + 0.8\right](0.03) - 0.85(0.01) = \left[\frac{1}{3}(0.02)(0.06)^2\right]\alpha$$

$$\alpha = 891 \text{ rad/s}^2 \qquad \textbf{Ans}$$

17-75. The two blocks A and B have a mass of m_A and m_B, respectively, where $m_B > m_A$. If the pulley can be treated as a disk of mass M, determine the acceleration of block A. Neglect the mass of the cord and any slipping on the pulley.

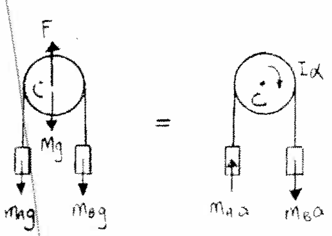


$a = \alpha r$

$$\circlearrowleft + \Sigma M_C = \Sigma (M_k)_C; \quad m_B g(r) - m_A g(r) = \left(\frac{1}{2}Mr^2\right)\alpha + m_B r^2 \alpha + m_A r^2 \alpha$$

$$\alpha = \frac{g(m_B - m_A)}{r\left(\frac{1}{2}M + m_B + m_A\right)}$$

$$a = \frac{g(m_B - m_A)}{\left(\frac{1}{2}M + m_B + m_A\right)} \qquad \textbf{Ans}$$



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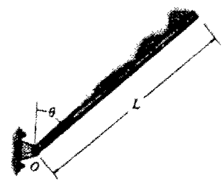
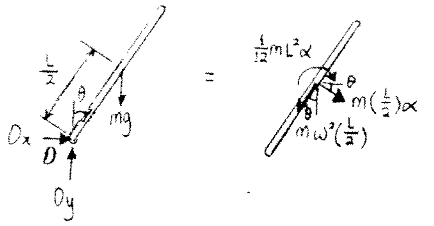
*17-76. The rod has a length L and mass m. If it is released from rest when $\theta \approx 0°$, determine its angular velocity as a function of θ. Also, express the horizontal and vertical components of reaction at the pin O as a function of θ.



$$\circlearrowleft + \Sigma M_O = \Sigma (M_k)_O; \quad mg\left(\frac{L}{2}\right)\sin\theta = m\left(\frac{L}{2}\right)(\alpha)\left(\frac{L}{2}\right) + \left(\frac{1}{12}mL^2\right)\alpha$$

$$mg\left(\frac{L}{2}\right)\sin\theta = \left(\frac{1}{3}mL^2\right)\alpha$$

$$\alpha = \frac{3}{2}\left(\frac{g}{L}\right)\sin\theta$$



$$\alpha \, d\theta = \omega \, d\omega$$

$$\int_0^{\theta} \frac{3}{2}\left(\frac{g}{L}\right)\sin\theta \, d\theta = \int_0^{\omega} \omega \, d\omega$$

$$-\left(\frac{3}{2}\right)\left(\frac{g}{L}\right)\cos\theta\Big|_0^{\theta} = \frac{1}{2}\omega^2$$

$$\omega = \sqrt{\frac{3g}{L}(1-\cos\theta)} \qquad \textbf{Ans}$$

$$+\uparrow \Sigma F_y = m(a_G)_y; \quad O_y - mg = -m\left(\frac{L}{2}\right)\left(\frac{3g}{L}\right)(1-\cos\theta)\cos\theta - m\left(\frac{L}{2}\right)\left(\frac{3}{2}\right)\left(\frac{g}{L}\right)\sin\theta(\sin\theta)$$

$$O_y = mg\left[1 - \frac{3}{2}(1-\cos\theta)\cos\theta - \frac{3}{4}\sin^2\theta\right]$$

$$O_y = mg\left(1 - 1.5\cos\theta + 1.5\cos^2\theta - 0.75\sin^2\theta\right) \qquad \textbf{Ans}$$

$$\xrightarrow{+} \Sigma F_x = m(a_G)_x; \quad O_x = m\left(\frac{L}{2}\right)\left(\frac{3}{2}\right)\left(\frac{g}{L}\sin\theta\right)\cos\theta - m\left(\frac{L}{2}\right)\left(\frac{3g}{L}\right)(1-\cos\theta)\sin\theta$$

$$O_x = mg(0.75\sin\theta\cos\theta - 1.5\sin\theta + 1.5\sin\theta\cos\theta)$$

$$O_x = mg\sin\theta(2.25\cos\theta - 1.5) \qquad \textbf{Ans}$$

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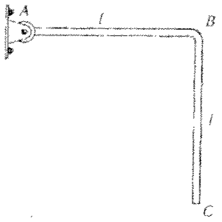
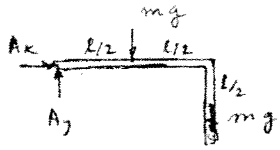
17-77. The two-bar assembly is released from rest in the position shown. Determine the initial bending moment at the fixed joint B. Each bar has a mass m and length l.





Assembly:

$$I_A = \frac{1}{3}ml^2 + \frac{1}{12}(m)(l)^2 + m(l^2 + (\frac{l}{2})^2)$$

$$= 1.667\,ml^2$$

$$\curvearrowleft + \Sigma M_A = I_A\,\alpha; \qquad mg(\frac{l}{2}) + mg(l) = (1.667ml^2)\alpha$$

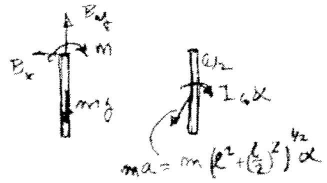
$$\alpha = \frac{0.9\,g}{l}$$

Segment BC:

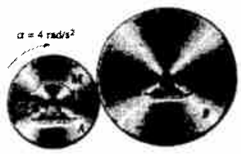
$$\curvearrowleft + \Sigma M_B = \Sigma(M_k)_B; \qquad M = \left[\frac{1}{12}ml^2\right]\alpha + m(l^2 + (\frac{l}{2})^2)^{1/2}\alpha(\frac{l/2}{l^2+(\frac{l}{2})^2})(\frac{l}{2})$$

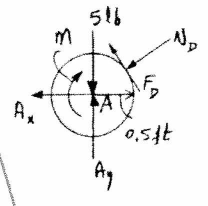
$$M = \frac{1}{3}ml^2\,\alpha = \frac{1}{3}ml^2(\frac{0.9g}{l})$$

$$M = 0.3gml \qquad \textbf{Ans}$$



17-78. Disk A has a weight of 5 lb and disk B has a weight of 10 lb. If no slipping occurs between them, determine the couple moment **M** which must be applied to disk A to give it an angular acceleration of 4 rad/s^2.





Disk A :

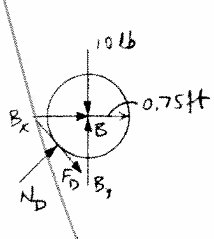
$$\circlearrowleft + \Sigma M_A = I_A\,\alpha_A; \quad M - F_D(0.5) = \left[\frac{1}{2}\left(\frac{5}{32.2}\right)(0.5)^2\right](4)$$

Disk B :

$$+\Sigma M_B = I_B\,\alpha_B; \quad F_D(0.75) = \left[\frac{1}{2}\left(\frac{10}{32.2}\right)(0.75)^2\right]\alpha_B$$

$$r_A\,\alpha_A = r_B\,\alpha_B$$

$$0.5(4) = 0.75\alpha_B$$

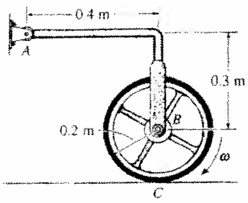


Solving :

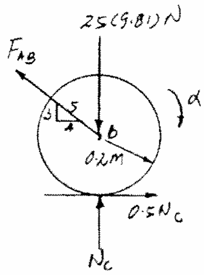
$\alpha_B = 2.67$ rad/s^2; $F_D = 0.311$ lb

$M = 0.233$ lb · ft **Ans**

17-79. The wheel has a mass of 25 kg and a radius of gyration $k_B = 0.15$ m. It is originally spinning at $\omega_1 = 40$ rad/s. If it is placed on the ground, for which the coefficient of kinetic friction is $\mu_C = 0.5$, determine the time required for the motion to stop. What are the horizontal and vertical components of reaction which the pin at A exerts on AB during this time? Neglect the mass of AB.



$$I_B = mk_B^2 = 25(0.15)^2 = 0.5625\ \text{kg}\cdot\text{m}^2$$



$$+\uparrow \Sigma F_y = m(a_G)_y; \quad \left(\tfrac{3}{5}\right) F_{AB} + N_C - 25(9.81) = 0 \qquad [1]$$

$$\xrightarrow{+} \Sigma F_x = m(a_G)_x; \quad 0.5N_C - \left(\tfrac{4}{5}\right) F_{AB} = 0 \qquad [2]$$

$$\circlearrowleft +\Sigma M_B = I_B\,\alpha; \quad 0.5N_C(0.2) = 0.5625(-\alpha) \qquad [3]$$

Solvings Eqs.[1], [2] and [3] yields :

$F_{AB} = 111.48$ N $\quad N_C = 178.4$ N

$\alpha = -31.71$ rad/s^2

$A_x = \frac{4}{5}F_{AB} = 0.8(111.48) = 89.2$ N **Ans**

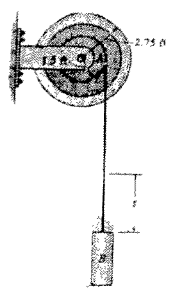
$A_y = \frac{3}{5}F_{AB} = 0.6(111.48) = 66.9$ N **Ans**

$\omega = \omega_0 + \alpha_c t$

$0 = 40 + (-31.71)t$

$t = 1.26$ s **Ans**

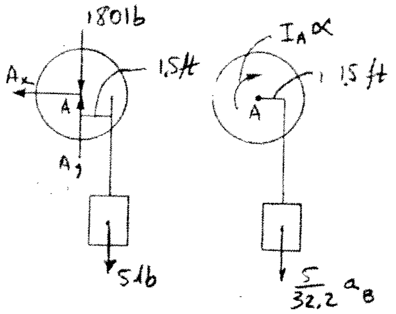
•17-80. The cord is wrapped around the inner core of the spool. If a 5-lb block B is suspended from the cord and released from rest, determine the spool's angular velocity when $t = 3$ s. Neglect the mass of the cord. The spool has a weight of 180 lb and the radius of gyration about the axle A is $k_A = 1.25$ ft. Solve the problem in two ways, first by considering the "system" consisting of the block and spool, and then by considering the block and spool separately.



System :

$$\circlearrowleft + \Sigma M_A = \Sigma (M_k)_A; \quad 5(1.5) = \left(\frac{180}{32.2}\right)(1.25)^2\,\alpha + \left(\frac{5}{32.2}\right)(1.5\alpha)(1.5)$$

$$\alpha = 0.8256 \text{ rad/s}^2$$



$$(\circlearrowleft +) \quad \omega = \omega_0 + \alpha_c t$$

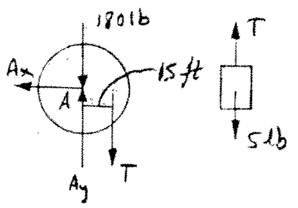
$$\omega = 0 + (0.8256)(3)$$

$$\omega = 2.48 \text{ rad/s} \qquad \textbf{Ans}$$

Also,

Spool :

$$\circlearrowleft + \Sigma M_A = I_A\,\alpha; \quad T(1.5) = \left(\frac{180}{32.2}\right)(1.25)^2\,\alpha$$



Weight :

$$+\downarrow \Sigma F_y = m(a_G)_y; \quad 5 - T = \left(\frac{5}{32.2}\right)(1.5\alpha)$$

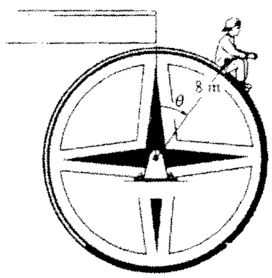
$$\alpha = 0.8256 \text{ rad/s}^2$$

$$(\circlearrowleft +) \quad \omega = \omega_0 + \alpha_c t$$

$$\omega = 0 + (0.8256)(3)$$

$$\omega = 2.48 \text{ rad/s} \qquad \textbf{Ans}$$

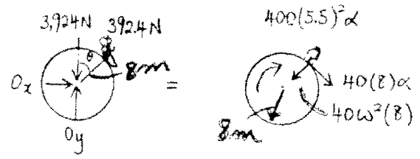
17-81. A 40-kg boy sits on top of the large wheel which has a mass of 400 kg and a radius of gyration $k_G = 5.5$ m. If the boy essentially starts from rest at $\theta = 0°$, and the wheel begins to rotate freely, determine the angle at which the boy begins to slip. The coefficient of static friction between the wheel and the boy is $\mu_s = 0.5$. Neglect the size of the boy in the calculation.



$$\circlearrowleft + \Sigma M_O = \Sigma(M_k)_O; \qquad 392.4(8\sin\theta) = 400(5.5)^2\alpha + 40(8)(\alpha)(8)$$

$$0.2141\sin\theta = \alpha$$

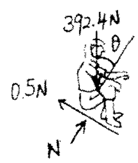
$$\alpha\, d\theta = \omega\, d\omega$$



$$\int_0^\theta 0.2141\sin\theta\, d\theta = \int_0^\omega \omega\, d\omega$$

$$-0.2141\cos\theta\Big|_0^\theta = \frac{1}{2}\omega^2$$

$$\omega^2 = 0.4283(1-\cos\theta)$$



$$+\swarrow \Sigma F_{y'} = m(a_G)_{y'}; \qquad 392.4\cos\theta - N = 40(\omega^2)(8)$$

$$+\searrow \Sigma F_{x'} = m(a_G)_{x'}; \qquad 392.4\sin\theta - 0.5N = 40(8)(\alpha)$$

$$N = 392.4\cos\theta - 137.05(1-\cos\theta) = 529.45\cos\theta - 137.05$$

$$392.4\sin\theta - 0.5(529.45\cos\theta - 137.05) = 320(0.2141\sin\theta)$$

$$323.89\sin\theta - 264.73\cos\theta + 68.52 = 0$$

$$-\sin\theta + 0.8173\cos\theta = 0.2116$$

Solve by trial and error

$\theta = 29.8°$ **Ans**

Note : The boy will loose contact with the wheel when $N = 0$, i.e.

$$N = 529.45\cos\theta - 137.05 = 0$$

$$\theta = 75.0° > 29.8°$$

Hence slipping occurs first.

17-82. The "Catherine wheel" is a firework that consists of a coiled tube of powder which is pinned at its center. If the powder burns at a constant rate of 20 g/s such that the exhaust gases always exert a force having a constant magnitude of 0.3 N, directed tangent to the wheel, determine the angular velocity of the wheel when 75% of the mass is burned off. Initially, the wheel is at rest and has a mass of 100 g and a radius of $r = 75$ mm. For the calculation, consider the wheel to always be a thin disk.

Mass of wheel when 75% of the powder is burned = 0.025 kg

Time to burn off 75% $= \dfrac{0.075\text{ kg}}{0.02\text{ kg/s}} = 3.75$ s

$m(t) = 0.1 - 0.02t$

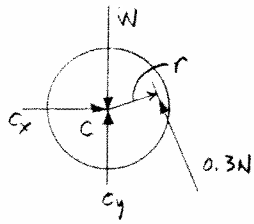
Mass of disk per unit area is

$$\rho_0 = \frac{m}{A} = \frac{0.1\text{ kg}}{\pi(0.075\text{ m})^2} = 5.6588\text{ kg/m}^2$$

At any time t,

$$5.6588 = \frac{0.1 - 0.02t}{\pi r^2}$$

$$r(t) = \sqrt{\frac{0.1 - 0.02t}{\pi(5.6588)}}$$



$$+\Sigma M_C = I_C\alpha; \qquad 0.3r = \frac{1}{2}mr^2\alpha$$

$$\alpha = \frac{0.6}{mr} = \frac{0.6}{(0.1 - 0.02t)\sqrt{\dfrac{0.1 - 0.02t}{\pi(5.6588)}}}$$

$$\alpha = 0.6\left(\sqrt{\pi(5.6588)}\right)[0.1 - 0.02t]^{-\frac{3}{2}}$$

$$\alpha = 2.530[0.1 - 0.02t]^{-\frac{3}{2}}$$

$d\omega = \alpha\, dt$

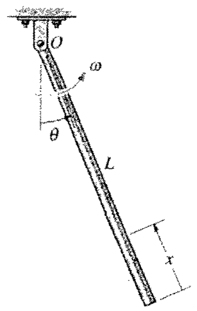
$$\int_0^\omega d\omega = 2.530\int_0^t [0.1 - 0.02t]^{-\frac{3}{2}}\, dt$$

$$\omega = 253\left[(0.1 - 0.02t)^{-\frac{1}{2}} - 3.162\right]$$

For $t = 3.75$ s,

$\omega = 800$ rad/s **Ans**

17-83. The bar has a weight per length of w. If it is rotating in the vertical plane at a constant rate ω about point O, determine the internal normal force, shear force, and moment as a function of x and θ.



$$a = \omega^2\left(L - \frac{x}{2}\right) \measuredangle^{\theta}$$

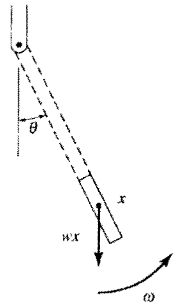
Forces:

$$\frac{wx}{g}\omega^2\left(L - \frac{x}{2}\right) \measuredangle^{\theta} = N \measuredangle^{\theta} + S \measuredangle_{\theta} + wx \downarrow \quad (1)$$

Moments:

$$I\alpha = M - S\left(\frac{x}{2}\right)$$

$$O = M - \frac{1}{2}Sx \qquad (2)$$



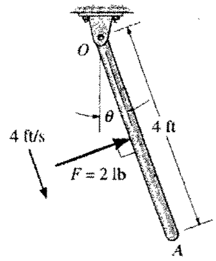
Solving (1) and (2),

$$N = wx\left[\frac{\omega^2}{g}\left(L - \frac{x}{2}\right) + \cos\theta\right] \quad \textbf{Ans}$$

$$S = wx\sin\theta \quad \textbf{Ans}$$

$$M = \frac{1}{2}wx^2\sin\theta \quad \textbf{Ans}$$

***17-84.** A force $F = 2$ lb is applied perpendicular to the axis of the 5-lb rod and moves from O to A at a constant rate of 4 ft/s. If the rod is at rest when $\theta = 0°$ and $\mathbf{F}$ is at O when $t = 0$, determine the rod's angular velocity at the instant the force is at A. Through what angle has the rod rotated when this occurs? The rod rotates in the *horizontal plane*.



$$I_O = \frac{1}{3}mR^2 = \frac{1}{3}\left(\frac{5}{32.2}\right)(4)^2 = 0.8282 \text{ slug}\cdot\text{ft}^2$$

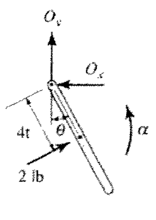
$$\circlearrowleft + \sum M_O = I_O\alpha: \quad 2(4t) = 0.8282(\alpha)$$

$$\alpha = 9.66t$$

$$d\omega = \alpha\, dt$$

$$\int_0^{\omega} d\omega = \int_0^{t} 9.66t\, dt$$

$$\omega = 4.83t^2$$



When $t = 1$ s,

$$\omega = 4.83(1)^2 = 4.83 \text{ rad/s} \quad \textbf{Ans}$$

$$d\theta = \omega\, dt$$

$$\int_0^{\theta} d\theta = \int_0^{t} 4.83t^2 dt$$

$$\theta = 1.61 \text{ rad} = 92.2° \quad \textbf{Ans}$$

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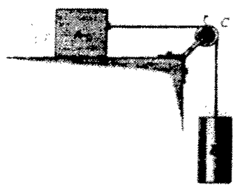
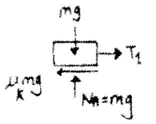
17-~~85~~. Block A has a mass m and rests on a surface having a coefficient of kinetic friction μ_k. The cord attached to A passes over a pulley at C and is attached to a block B having a mass $2m$. If B is released, determine the acceleration of A. Assume that the cord does not slip over the pulley. The pulley can be approximated as a thin disk of radius r and mass $\frac{1}{4}m$. Neglect the mass of the cord.



Block A :

$\xrightarrow{+} \Sigma F_x = ma_x; \quad T_1 - \mu_k mg = ma \quad (1)$



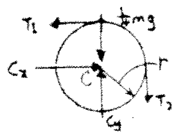
Block B :

$+\downarrow \Sigma F_y = ma_y; \quad 2mg - T_2 = 2ma \quad (2)$

Pulley C :

$\circlearrowleft + \Sigma M_C = I_G\alpha; \quad T_2 r - T_1 r = \left[\frac{1}{2}\left(\frac{1}{4}m\right)r^2\right]\left(\frac{a}{r}\right)$

$$T_2 - T_1 = \frac{1}{8}ma \quad (3)$$



Substituting Eqs. (1) and (2) into (3),

$$2mg - 2ma - (ma + \mu_k mg) = \frac{1}{8}ma$$

$$2mg - \mu_k mg = \frac{1}{8}ma + 3ma$$

$$(2 - \mu_k)g = \frac{25}{8}a$$

$$a = \frac{8}{25}(2 - \mu_k)g \quad \textbf{Ans}$$

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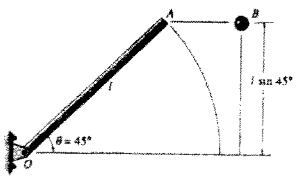
17-~~86~~. The slender rod of mass m is released from rest when $\theta = 45°$. At the same instant ball B having the same mass m is released. Will B or the end A of the rod have the greatest speed when they pass the horizontal ($\theta = 0°$)? What is the difference in their speeds?

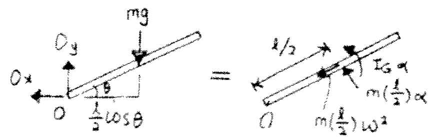


Rod :

$\circlearrowleft + \Sigma M_O = \Sigma(M_k)_O; \quad mg\left(\frac{l}{2}\right)\cos\theta = -\frac{1}{12}(m)(l)^2\alpha - m\left(\frac{l}{2}\right)\alpha\left(\frac{l}{2}\right)$

$$mg\left(\frac{l}{2}\right)\cos\theta = -\frac{1}{3}(m)(l)^2\alpha$$

$$-\frac{3g}{2l}\cos\theta = \alpha$$



$$\omega\, d\omega = \alpha\, d\theta$$

$$\int_0^{\omega} \omega\, d\omega = -\int_{\frac{\pi}{4}}^{0} \frac{3g}{2l}\cos\theta\, d\theta$$

$$\frac{1}{2}\omega^2 = -\left(\frac{3g}{2l}\right)\sin\theta\Big|_{\frac{\pi}{4}}^{0}$$

$$\omega = \sqrt{\frac{3g}{l}\left(\frac{1}{\sqrt{2}}\right)}$$

$$v_A = \sqrt{\frac{3g}{l\sqrt{2}}}\,(l) = \frac{\sqrt{3gl}}{1.1892}$$

$$v_A = 1.46\sqrt{gl}$$

Ball :

$(+\downarrow) \quad v^2 = v_0^2 + 2a_c(s - s_0)$

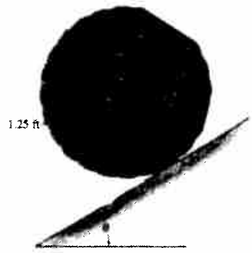
$$v_B^2 = 0 + 2g(l\sin 45° - 0)$$

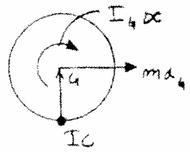
$$v_B = 1.19\sqrt{gl}$$

Point A has the greatest speed.

$$\Delta v = 0.267\sqrt{gl} \quad \textbf{Ans}$$

17-87. If the disk in Fig. 17-21*a* *rolls without slipping,* show that when moments are summed about the instantaneous center of zero velocity, *IC*, it is possible to use the moment equation $\Sigma M_{IC} = I_{IC}\alpha$, where I_{IC} represents the moment of inertia of the disk calculated about the instantaneous axis of zero velocity.





$\curvearrowleft + \Sigma M_{IC} = \Sigma(M_k)_{IC};\qquad \Sigma M_{IC} = I_G\alpha + (ma_G)r$

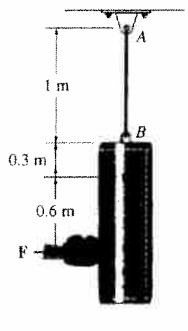
Since there is no slipping, $\quad a_G = \alpha r$

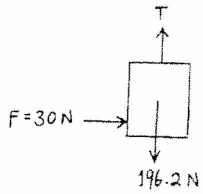
Thus, $\quad \Sigma M_{IC} = \left(I_G + mr^2\right)\alpha$

By the parallel – axis thoerem, the term in parenthesis represents I_{IC}. Thus,

$\Sigma M_{IC} = I_{IC}\alpha$ **Q.E.D.**

***17-88.** The 20-kg punching bag has a radius of gyration about its center of mass G of $k_G = 0.4$ m. If it is initially at rest and is subjected to a horizontal force $F = 30$ N, determine the initial angular acceleration of the bag and the tension in the supporting cable AB.





$\xrightarrow{+} \Sigma F_x = m(a_G)_x;\qquad 30 = 20(a_G)_x$

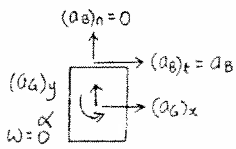
$+\uparrow \Sigma F_y = m(a_G)_y;\qquad T - 196.2 = 20(a_G)_y$

$\curvearrowleft + \Sigma M_G = I_G\alpha;\qquad 30(0.6) = 20(0.4)^2\alpha$

$\alpha = 5.62 \text{ rad/s}^2$ **Ans**

$(a_G)_x = 1.5 \text{ m/s}^2$

$\mathbf{a}_B = \mathbf{a}_G + \mathbf{a}_{B/G}$



$a_B\,\mathbf{i} = (a_G)_y\,\mathbf{j} + (a_G)_x\,\mathbf{i} - \alpha(0.3)\mathbf{i}$

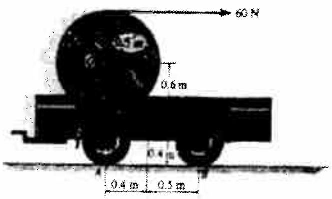
$(+\uparrow)\qquad (a_G)_y = 0$

Thus,

$T = 196 \text{ N}$ **Ans**

52

17-~~89~~. The trailer has a mass of 580 kg and a mass center at G, whereas the spool has a mass of 200 kg, mass center at O, and a radius of gyration about an axis passing through O of $k_O = 0.45$ m. If a force of 60 N is applied to the cable, determine the angular acceleration of the spool and the acceleration of the trailer. The wheels have negligible mass and are free to roll.



System :

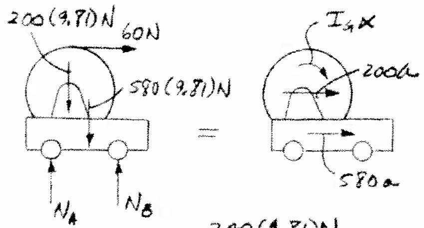
$\xrightarrow{+} \Sigma F_x = m(a_G)_x; \quad 60 = 200a + 580a$

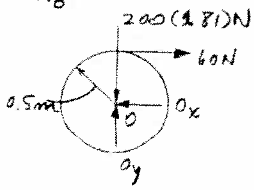
$a = 0.0769 \text{ m/s}^2$ **Ans**

Spool :

$\circlearrowleft + \Sigma M_O = I_O\alpha; \quad 60(0.5) = 200(0.45)^2\alpha$

$\alpha = 0.741 \text{ rad/s}^2$ **Ans**





53 100kN

17-~~90~~. The rocket has a weight of ~~20 000 lb~~, mass center at G, and radius of gyration about the mass center of k_G = ~~21 ft~~ 7m when it is fired. Each of its two engines provides a thrust T = ~~50 000 lb~~. 250 kN At a given instant, engine A suddenly fails to operate. Determine the angular acceleration of the rocket and the acceleration of its nose B.

$\circlearrowleft + \Sigma M_G = I_G\alpha; \quad \cancel{50\,000}^{250}(1.5) = \frac{\cancel{20\,000}^{100}}{\cancel{32.2}_{9.81}}(\cancel{21}^{7})^2\alpha$

α = ~~0.2738 rad/s² = 0.274 rad/s²~~ 0.50 rad/s² **Ans**

$+\uparrow \Sigma F_y = m(a_G)_y; \quad \cancel{50\,000}^{250} - \cancel{20\,000}^{100} = \frac{\cancel{20\,000}^{100}}{\cancel{32.2}_{9.81}}a_G$

a_G = ~~48.3 ft/s²~~ 14.71 m/s²

$\mathbf{a}_B = \mathbf{a}_G + \mathbf{a}_{B/G}$

Since $\omega = 0$

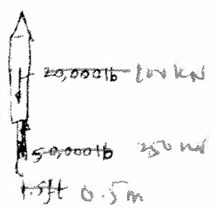
$\mathbf{a}_B = \cancel{48.3}^{14.71}\mathbf{j} - \cancel{0.2738}^{0.5}(\cancel{30}^{10})\mathbf{i}$

= ~~48.3j − 8.214i~~ 14.71j − 5.0i

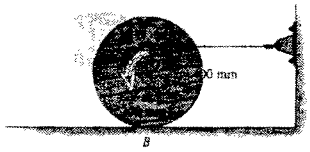
15.53 m/s²

$a_B = \sqrt{(\cancel{48.3}_{14.71})^2 + (\cancel{8.214}_{5.0})^2}$ = ~~49.0 ft/s²~~ **Ans**

$\theta = \tan^{-1}\frac{\cancel{48.3}^{14.71}}{\cancel{8.214}_{5.0}}$ = ~~80.3°~~ 71.23° **Ans**



17-91. The spool and wire wrapped around its core have a mass of 20 kg and a centroidal radius of gyration $k_G = 250$ mm. If the coefficient of kinetic friction at the ground is $\mu_k = 0.1$, determine the angular acceleration of the spool when the 30-N·m couple is applied.



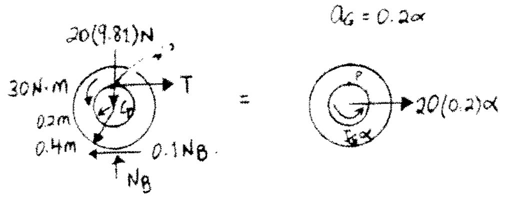
$a_G = \alpha(0.2)$

$+\uparrow \Sigma F_y = m(a_G)_y$; $N_B - 20(9.81) = 0$, $N_B = 196.2$ N

$\circlearrowleft + \Sigma M_P = \Sigma(M_k)_P$; $30 - 0.1(196.2)(0.6) = 20(0.2)[\alpha(0.2)] + [20(0.25)^2]\alpha$

$\alpha = 8.89 \text{ rad/s}^2$ **Ans**

Also,



$\xrightarrow{+} \Sigma F_x = m(a_G)_x$; $T - 0.1N_B = 20(0.2)\alpha$

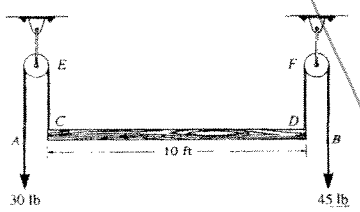
$+\uparrow \Sigma F_y = m(a_G)_y$; $N_B - 20(9.81) = 0$, $N_B = 196.2$ N

$\circlearrowleft + \Sigma M_G = I_G\alpha$; $30 - T(0.2) - 0.1N_B(0.4) = 20(0.25)^2\alpha$

$\alpha = 8.89 \text{ rad/s}^2$ **Ans**

$T = 55.2$ N

***17-92.** The uniform 50-lb board is suspended from cords at C and D. If these cords are subjected to constant forces of 30 lb and 45 lb, respectively, determine the acceleration of the board's center and the board's angular acceleration. Assume the board is a thin plate. Neglect the mass of the pulleys at E and F.



$+\uparrow \Sigma F_y = m(a_G)_y$; $45 + 30 - 50 = \frac{50}{32.2}a_G$

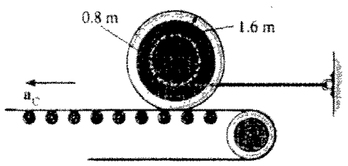
$a_G = 16.1 \text{ ft/s}^2$ **Ans**

$\circlearrowleft + \Sigma M_G = I_G\alpha$; $-30(5) + 45(5) = [\frac{1}{12}(\frac{50}{32.2})(10)^2]\alpha$

$\alpha = 5.80 \text{ rad/s}^2$ **Ans**

55

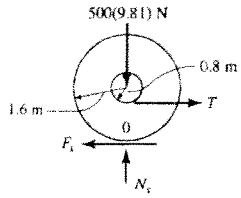
17-93. The spool has a mass of 500 kg and a radius of gyration $k_G = 1.30$ m. It rests on the surface of a conveyor belt for which the coefficient of static friction is $\mu_s = 0.5$ and the coefficient of kinetic friction is $\mu_k = 0.4$. If the conveyor accelerates at $a_C = 1\ \text{m/s}^2$, determine the initial tension in the wire and the angular acceleration of the spool. The spool is originally at rest.



$\overset{+}{\rightarrow}\sum F_x = m(a_G)_x;\quad -F_s + T = 500a_G$

$+\uparrow\sum F_y = m(a_G)_y;\quad N_s - 500(9.81) = 0$

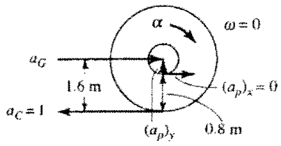
$\curvearrowleft + \sum M_G = I_G\alpha;\quad F_s(1.6) - T(0.8) = 500(1.30)^2\alpha$



$\mathbf{a}_P = \mathbf{a}_C + \mathbf{a}_{P/G}$

$(a_P)_y\mathbf{j} = a_G\mathbf{i} - 0.8\alpha\mathbf{i}$

$a_G = 0.8\alpha$



$N_s = 4905$ N

Assume no slipping

$\alpha = \frac{a_C}{0.8} = \frac{1}{0.8} = 1.25$ rad/s **Ans**

$a_G = 0.8(1.25) = 1\ \text{m/s}^2$

$T = 2.32$ kN **Ans**

$F_s = 1.82$ kN

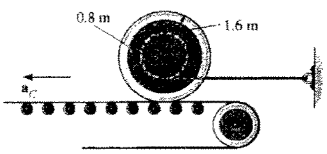
Since

$(F_s)_{max} = 0.5(4.905) = 2.45 > 1.82$

(No slipping occurs)

56

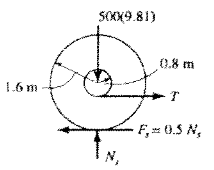
17-94. The spool has a mass of 500 kg and a radius of gyration $k_G = 1.30$ m. It rests on the surface of a conveyor belt for which the coefficient of static friction is $\mu_s = 0.5$. Determine the greatest acceleration a_C of the conveyor so that the spool will not slip. Also, what are the initial tension in the wire and the angular acceleration of the spool? The spool is originally at rest.



$\overset{+}{\rightarrow}\sum F_x = m(a_G)_x;\quad T - 0.5N_s = 500a_G$

$+\uparrow\sum F_y = m(a_G)_y;\quad N_s - 500(9.81) = 0$

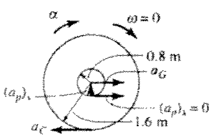
$\curvearrowleft + \sum M_G = I_G\alpha;\quad 0.5N_s(1.6) - T(0.8) = 500(1.30)^2\alpha$



$a_P = a_C + a_{P/G}$

$(a_p)_y\mathbf{j} = a_G\mathbf{i} - 0.8\alpha\mathbf{i}$

$a_G = 0.8\alpha$



Solving;

$N_s = 4905$ N

$T = 3.13$ kN **Ans**

$\alpha = 1.684$ rad/s **Ans**

$a_G = 1.347\ \text{m/s}^2$ **Ans**

Since no slipping

$\mathbf{a}_C = \mathbf{a}_G + \mathbf{a}_{C/G}$

$a_C = 1.347\mathbf{i} - (1.684)(1.6)\mathbf{i}$

$a_C = 1.35\ \text{m/s}^2$ **Ans**

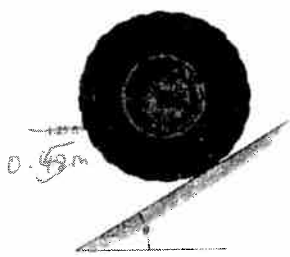
Also,

$\curvearrowleft + \sum M_{IC} = I_{IC}\alpha;\quad 0.5N_s(0.8) = [500(1.30)^2 + 500(0.8)^2]\alpha$

Since $N_s = 4905$ N

$\alpha = 1.684$ rad/s

17-95. The wheel has a weight of ~~30 lb~~ 150N and a radius of gyration of k_G = ~~0.6 ft~~ 0.2M. If the coefficients of static and kinetic friction between the wheel and the plane are $\mu_s = 0.2$ and $\mu_k = 0.15$, determine the wheel's angular acceleration as it rolls down the incline. Set $\theta = 12°$.



$+\swarrow \Sigma F_x = m(a_G)_x$; $\quad \cancel{30}\,150 \sin 12° - F = \left(\dfrac{\cancel{30}\,150}{\cancel{32.2}\,9.81}\right)a_G$

$+\nwarrow \Sigma F_y = m(a_G)_y$; $\quad N - \cancel{30}\,150 \cos 12° = 0$

$\circlearrowleft + \Sigma M_G = I_G\alpha$; $\quad F(\cancel{1.25}\,0.5) = \left[\left(\dfrac{\cancel{30}\,150}{\cancel{32.2}\,9.81}\right)(\cancel{0.6}\,0.2)^2\right]\alpha$

Assume the wheel does not slip.

$a_G = (\cancel{1.25}\,0.5)\alpha$

Solving,

F = ~~1.17 lb~~ 4.29 N

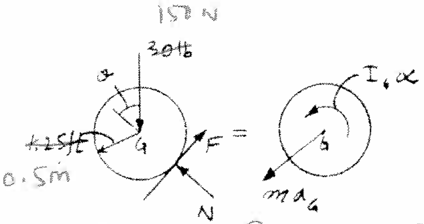
N = ~~29.34 lb~~ 146.72 N

a_G = 5.44 ~~ft/s²~~ 1.76 m/s²

α = ~~4.35 rad/s²~~ 3.52 rad/s² **Ans**

$F_{max} = 0.2(\cancel{29.34}) = 5.87$ lb > 1.17 lb OK

146.72 = 29.34 N > 4.29 N ok



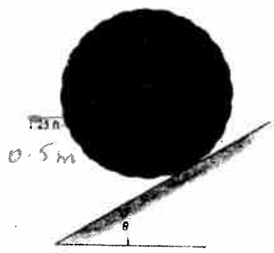
F = 31.2 − 15.3 α = 31.2 − 7.65α

F = ~~6.12α~~ 1.22α

α = 3 ~~78~~ 3.52

F =

*17-96. The wheel has a weight of ~~30~~ lb 150N and a radius of gyration of k_G = ~~0.6 ft~~ 0.2m. If the coefficients of static and kinetic friction between the wheel and the plane are $\mu_s = 0.2$ and $\mu_k = 0.15$, determine the maximum angle θ of the inclined plane so that the wheel rolls without slipping.



Since wheel is on the verge of slipping.

$+\swarrow \Sigma F_x = m(a_G)_x$; $\quad \cancel{30}\,150 \sin\theta - 0.2N = \left(\dfrac{\cancel{30}\,150}{\cancel{32.2}\,9.81}\right)(\cancel{1.25}\,0.5\,\alpha) \qquad (1)$

$+\nwarrow \Sigma F_y = m(a_G)_y$; $\quad N - \cancel{30}\,150 \cos\theta = 0 \qquad (2)$

$\circlearrowleft + \Sigma M_G = I_G\alpha$; $\quad 0.2N(\cancel{1.25}\,0.5) = \left[\left(\dfrac{\cancel{30}\,150}{\cancel{32.2}\,9.81}\right)(\cancel{0.6}\,0.2)^2\right]\alpha \qquad (3)$

→ N = 150 cos θ

α = N / 6.12 = 25.53 cos θ

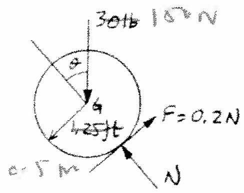
Subsituting Eqs. (2) and (3) into Eq. (1),

$30 \sin\theta - 6 \cos\theta = 26.042 \cos\theta$

$30 \sin\theta = 32.042 \cos\theta$

$\tan\theta = 1.068$

$\theta = 46.9°$ **Ans**

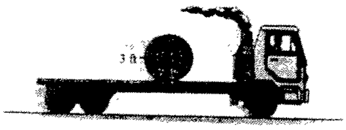


150 sin θ − 30 cos θ = 193.7 cos θ

150 sin θ = 223.7 cos θ

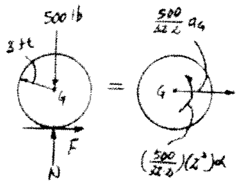
tan θ = 1.49 ≃ θ = 56.2°

17-97. The truck carries the spool which has a weight of 500 lb and a radius of gyration of $k_G = 2$ ft. Determine the angular acceleration of the spool if it is not tied down on the truck and the truck begins to accelerate at 3 ft/s². Assume the spool does not slip on the bed of the truck.



$\xrightarrow{+} \Sigma F_x = m(a_G)_x$; $\quad F = \left(\frac{500}{32.2}\right)a_G \quad (1)$

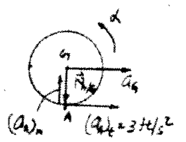
$\circlearrowleft + \Sigma M_G = I_G\alpha$; $\quad F(3) = \left(\frac{500}{32.2}\right)(2)^2\alpha \quad (2)$



$\mathbf{a}_A = \mathbf{a}_G + (\mathbf{a}_{A/G})_t + (\mathbf{a}_{A/G})_n$

$\left[\underset{\rightarrow}{(a_A)_t}\right] + \left[\underset{\uparrow}{(a_A)_n}\right] = \left[\underset{\rightarrow}{a_G}\right] + \left[\underset{\rightarrow}{3\alpha}\right] + \left[\underset{\uparrow}{(a_{A/G})_n}\right]$

$(\xrightarrow{+}) \quad 3 = a_G + 3\alpha \quad (3)$

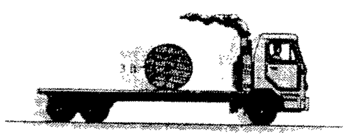


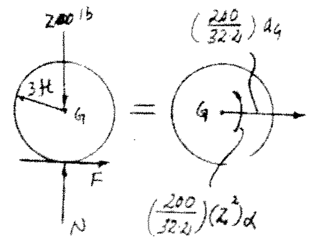
Solving Eqs. (1), (2) and (3) yields :

$F = 14.33$ lb $\quad a_G = 0.923$ ft/s²

$\alpha = 0.692$ rad/s² **Ans**

17-98. The truck carries the spool which has a weight of 200 lb and a radius of gyration of $k_G = 2$ ft. Determine the angular acceleration of the spool if it is not tied down on the truck and the truck begins to accelerate at 5 ft/s². The coefficients of static and kinetic friction between the spool and the truck bed are $\mu_s = 0.15$ and $\mu_k = 0.1$, respectively.





$+\uparrow \Sigma F_y = m(a_G)_y$; $\quad N - 200 = 0 \quad N = 200$ lb

$\xrightarrow{+} \Sigma F_x = m(a_G)_x$; $\quad F = \left(\frac{200}{32.2}\right)a_G \quad (1)$

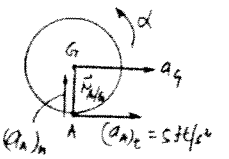
$\circlearrowleft + \Sigma M_G = I_G\alpha$; $\quad F(3) = \left(\frac{200}{32.2}\right)(2)^2\alpha \quad (2)$

Assume no slipping occurs at the point of contact. Hence $(a_A)_t = 5$ ft/s².

$\mathbf{a}_A = \mathbf{a}_G + (\mathbf{a}_{A/G})_t + (\mathbf{a}_{A/G})_n$

$\left[\underset{\rightarrow}{(a_A)_t}\right] + \left[\underset{\uparrow}{(a_A)_n}\right] = \left[\underset{\rightarrow}{a_G}\right] + \left[\underset{\rightarrow}{3\alpha}\right] + \left[\underset{\uparrow}{(a_{A/G})_n}\right]$

$(\xrightarrow{+}) \quad 5 = a_G + 3\alpha \quad (3)$

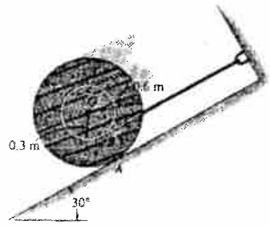


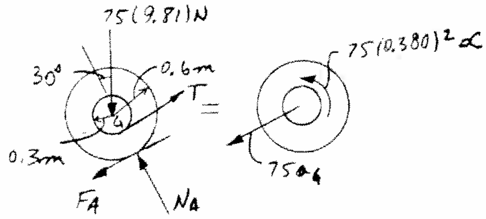
Solving Eqs. (1), (2) and (3) yields :

$F = 9.556$ lb $\quad a_G = 1.538$ ft/s²

$\alpha = 1.15$ rad/s² **Ans**

17-99. The spool has a mass of 75 kg and a radius of gyration $k_G = 0.380$ m. It rests on the inclined surface for which the coefficient of kinetic friction is $\mu_k = 0.15$. If the spool is released from rest and slips at A, determine the initial tension in the cord and the angular acceleration of the spool.





$F_A = 0.15N_A$

$a_G = 0.3\alpha$

$\nearrow + \Sigma F_{x'} = m(a_G)_{x'};$ $\quad 75(9.81)\sin 30^\circ - T + 0.15N_A = 75(0.3\alpha)$

$\nwarrow + \Sigma F_{y'} = m(a_G)_{y'};$ $\quad N_A - 75(9.81)\cos 30^\circ = 0$

$\circlearrowleft + \Sigma M_G = I_G\alpha;$ $\quad T(0.3) - (0.15N_A)(0.6) = \left[75(0.380)^2\right]\alpha$

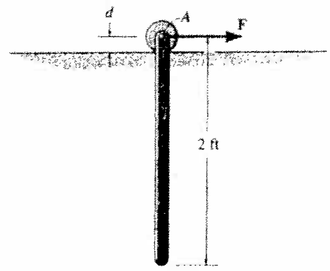
Solving,

$N_A = 637$ N

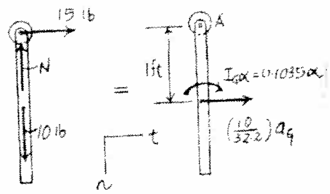
$\alpha = 4.65$ rad/s^2 **Ans**

$T = 359$ N **Ans**

***17-100.** A uniform rod having a weight of 10 lb is pin-supported at A from a roller which rides on a horizontal track. If the rod is originally at rest, and a horizontal force of $F = 15$ lb is applied to the roller, determine the acceleration of the roller. Neglect the mass of the roller and its size d in the computations.



Equation of Motion: The mass moment of inertia of the rod about its mass center is given by $I_G = \frac{1}{12}ml^2 = \frac{1}{12}\left(\frac{10}{32.2}\right)(2^2) = 0.1035$ slug · ft². At the instant force **F** is applied, the angular velocity of the rod $\omega = 0$. Thus, the normal component of acceleration of the mass center for the rod $(a_G)_n = 0$. Applying Eq. 17 – 16, we have



$\Sigma F_t = m(a_G)_t;\qquad 15 = \left(\frac{10}{32.2}\right)a_G \qquad a_G = 48.3 \text{ ft/s}^2$

$\curvearrowleft + \Sigma M_A = \Sigma(M_k)_A;\qquad 0 = \left(\frac{10}{32.2}\right)(48.3)(1) - 0.1035\alpha$

$\alpha = 144.9 \text{ rad/s}^2$

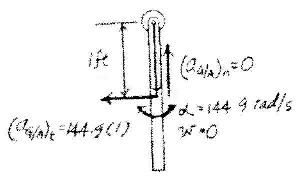
Kinematic: Since $\omega = 0$, $(a_{G/A})_n = 0$. The acceleration of roller A can be obtain by analyzing the motion of points A and G. Applying Eq. 16 – 17, we have

$$\mathbf{a}_G = \mathbf{a}_A + (\mathbf{a}_{G/A})_t + (\mathbf{a}_{G/A})_n$$

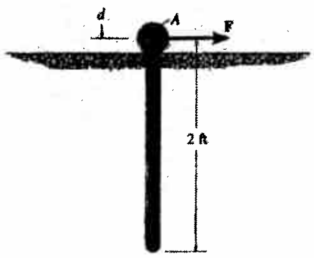
$$\begin{bmatrix} 48.3 \\ \rightarrow \end{bmatrix} = \begin{bmatrix} a_A \\ \rightarrow \end{bmatrix} + \begin{bmatrix} 144.9(1) \\ \leftarrow \end{bmatrix} + [0]$$

$(\overset{+}{\rightarrow})\qquad 48.3 = a_A - 144.9$

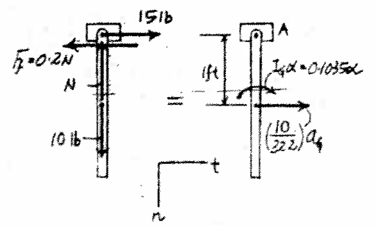
$a_A = 193 \text{ ft/s}^2 \qquad$ **Ans**



17-101. Solve Prob. 17–100 assuming that the roller at A is replaced by a slider block having a negligible mass. The coefficient of kinetic friction between the block and the track is $\mu_k = 0.2$. Neglect the dimension d and the size of the block in the computations.



Equation of Motion: The mass moment of inertia of the rod about its mass center is given by $I_G = \frac{1}{12}ml^2 = \frac{1}{12}\left(\frac{10}{32.2}\right)(2^2) = 0.1035$ slug · ft². At the instant force **F** is applied, the angular velocity of the rod $\omega = 0$. Thus, the normal component of acceleration of the mass center for the rod $(a_G)_n = 0$. Applying Eq. 17 – 16, we have



$\Sigma F_n = m(a_G)_n;\qquad 10 - N = 0 \qquad N = 10.0 \text{ lb}$

$\Sigma F_t = m(a_G)_t;\qquad 15 - 0.2(10.0) = \left(\frac{10}{32.2}\right)a_G \qquad a_G = 41.86 \text{ ft/s}^2$

$\curvearrowleft + \Sigma M_A = \Sigma(M_k)_A;\qquad 0 = \left(\frac{10}{32.2}\right)(41.86)(1) - 0.1035\alpha$

$\alpha = 125.58 \text{ rad/s}^2$

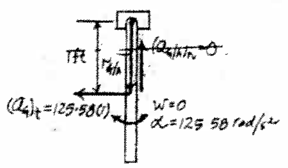
Kinematic: Since $\omega = 0$, $(a_{G/A})_n = 0$. The acceleration of block A can be obtain by analyzing the motion of points A and G. Applying Eq. 16 – 17, we have

$$\mathbf{a}_G = \mathbf{a}_A + (\mathbf{a}_{G/A})_t + (\mathbf{a}_{G/A})_n$$

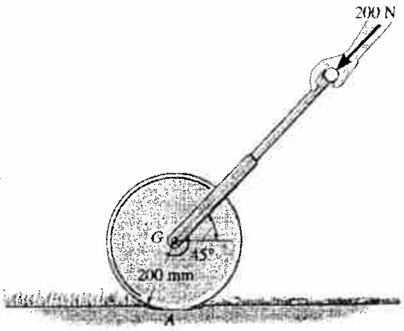
$$\begin{bmatrix} 41.86 \\ \rightarrow \end{bmatrix} = \begin{bmatrix} a_A \\ \rightarrow \end{bmatrix} + \begin{bmatrix} 125.58(1) \\ \leftarrow \end{bmatrix} + [0]$$

$(\overset{+}{\rightarrow})\qquad 41.86 = a_A - 125.58$

$a_A = 167 \text{ ft/s}^2 \qquad$ **Ans**



17-102. The lawn roller has a mass of 80 kg and a radius of gyration $k_G = 0.175$ m. If it is pushed forward with a force of 200 N when the handle is at 45°, determine its angular acceleration. The coefficients of static and kinetic friction between the ground and the roller are $\mu_s = 0.12$ and $\mu_k = 0.1$, respectively.



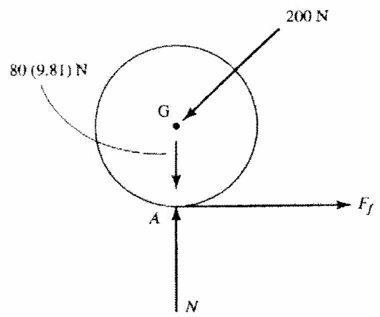
Assume no slipping.

$I_A = I_G + md^2 = 80(0.175)^2 + 80(0.200)^2 = 5.65\ \text{kg}\cdot\text{m}^2$

$M_A = 200\cos 45°(0.200) = 28.284\ \text{N}\cdot\text{m}$

$M_A = I_A\alpha$

$\alpha = \frac{28.284}{5.65} = 5.01\ \text{rad/s}^2$ **Ans**



Check no slippage assumption.

$(\uparrow +)\sum F_y = 0 \quad -200\sin 45° - 80(9.81) + N = 0$

$N = 926.22$ N

$(F_f)_{max} = 0.12(926.22) = 111.15$ N

$I_G = 80(0.175)^2 = 2.45\ \text{kg}\cdot\text{m}^2$

$M_G = I_G\alpha = 2.45(5.01) = 12.27\ \text{N}\cdot\text{m}$

$F_f = \frac{12.27}{0.200} = 61.4\ \text{N} < 111.15\ \text{N}$ **O.K.**

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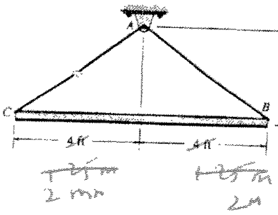
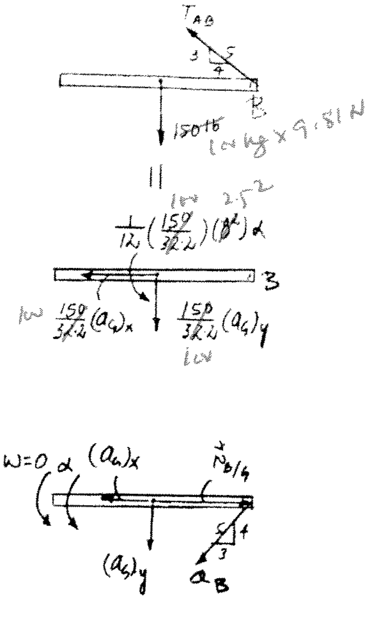
17-103. The slender ~~150-lb~~ 100 kg bar is supported by two cords AB and AC. If cord AC suddenly breaks, determine the initial angular acceleration of the bar and the tension in cord AB.





Equations of motion :

$\overset{+}{\leftarrow}\Sigma F_x = m(a_G)_x;\quad \frac{4}{5}T_{AB} = \left(\frac{150}{32.2}\right)(a_G)_x \quad (1)$ (100)

$+\uparrow\Sigma F_y = m(a_G)_y;\quad \frac{3}{5}T_{AB} - \cancel{150} = -\left(\frac{150}{32.2}\right)(a_G)_y \quad (2)$ (100 × 9.81; 100)

$\circlearrowleft + \Sigma M_B = \Sigma(M_k)_B;\quad 150(4) = \frac{1}{12}\left(\frac{150}{32.2}\right)(8)^2\alpha + \left(\frac{150}{32.2}\right)(a_G)_y\,(4) \quad (3)$

100 × 9.81 × ~~1.25~~ 2   100   25/4   100   ~~1.25~~ 2

Kinematics :

$\mathbf{a}_B = \mathbf{a}_G + (\mathbf{a}_{B/G})_t + (\mathbf{a}_{B/G})_n$

$$\left[\underset{\overset{5}{\swarrow}\overset{4}{}\,3}{a_B}\right] = \left[\underset{\leftarrow}{(a_G)_x}\right] + \left[\underset{\downarrow}{(a_G)_y}\right] + \left[\underset{\uparrow}{4\alpha}\right] + [0]$$

$(\overset{+}{\leftarrow})\qquad \frac{3}{5}a_B = (a_G)_x \qquad (4)$

$(+\downarrow)\qquad \frac{4}{5}a_B = (a_G)_y - \cancel{4}\,2\alpha \qquad (5)$

Solving Eqs. (1) – (5) yields :

$\alpha = \cancel{4.18\ \text{rad/s}^2}$ ~~8.02~~ 2.55 rad/s² $T_{AB} = \cancel{43.3\ \text{lb}}$ 283 N   **Ans**

$(a_G)_y = \cancel{26.63\ \text{ft/s}^2}$ 8.11 m/s² $(a_G)_x = \cancel{7.43\ \text{ft/s}^2}$ 2.26 m/s² $a_B = \cancel{12.38\ \text{ft/s}^2}$ 3.77 m/s²

~~43.540 m/s²~~

$\frac{5W}{4}(a_G)_x = -\frac{5W}{3}(a_G)_y + \frac{150 \times 9.81 \times 5}{3}$

$\frac{5}{3}(a_G)_x = \frac{5}{4}\left((a_G)_y - 2\alpha\right)$

$(a_G)_x = \frac{3}{4}(a_G)_y - \alpha\frac{3}{2}$

$-\frac{4}{3}(a_G)_y + \frac{14.71 \times 4}{3} = \frac{3}{4}(a_{Gy}) - \alpha\frac{3}{2}$

$\left(-\frac{4}{3} - \frac{1}{4}\right)a_{Gy} = -\alpha\frac{3}{2} + 19.62$

$a_{Gy} = +\cancel{10.9}\ \ldots 8.11$

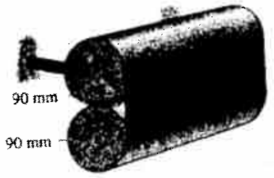
$.947\alpha + 12.39$

~~1226 = 52.08α + 115α − 2264~~

$1962 = 133.3\alpha + 189.44 + 2478$

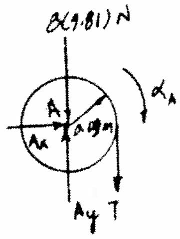
$\alpha = 13.76$

•17-104. A long strip of paper is wrapped into two rolls, each having a mass of 8 kg. Roll *A* is pin supported about its center whereas roll *B* is not centrally supported. If *B* is brought into contact with *A* and released from rest, determine the initial tension in the paper between the rolls and the angular acceleration of each roll. For the calculation, assume the rolls to be approximated by cylinders.



For roll A.

$\circlearrowleft + \Sigma M_A = I_A\,\alpha; \qquad T(0.09) = \frac{1}{2}(8)(0.09)^2\alpha_A \qquad (1)$



For roll *B*

$\circlearrowleft + \Sigma M_O = \Sigma(M_k)_O; \qquad 8(9.81)(0.09) = \frac{1}{2}(8)(0.09)^2\alpha_B + 8a_B(0.09) \qquad (2)$

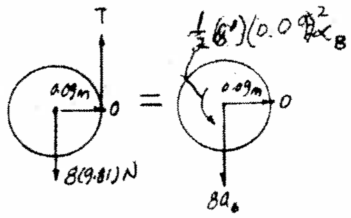
$+\uparrow \Sigma F_y = m(a_G)_y; \qquad T - 8(9.81) = -8a_B \qquad (3)$

Kinematics :

$$\mathbf{a}_B = \mathbf{a}_O + (\mathbf{a}_{B/O})_t + (\mathbf{a}_{B/O})_n$$

$$\begin{bmatrix} a_B \\ \downarrow \end{bmatrix} = \begin{bmatrix} a_O \\ \downarrow \end{bmatrix} + \begin{bmatrix} \alpha_B(0.09) \\ \downarrow \end{bmatrix} + [0]$$

$(+\downarrow) \qquad a_B = a_O + 0.09\alpha_B \qquad (4)$



also, $\qquad (+\downarrow) \qquad a_O = \alpha_A(0.09) \qquad (5)$

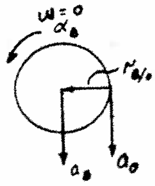
Solving Eqs. (1) – (5) yields :

$\alpha_A = 43.6\text{ rad/s}^2$ **Ans**

$\alpha_B = 43.6\text{ rad/s}^2$ **Ans**

$T = 15.7\text{ N}$ **Ans**

$a_B = 7.85\text{ m/s}^2 \qquad a_O = 3.92\text{ m/s}^2$



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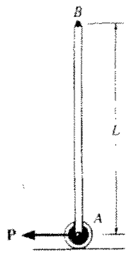
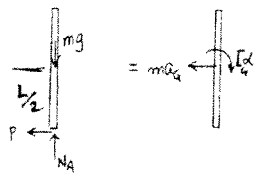
17-~~105~~. The uniform bar of mass m and length L is balanced in the vertical position when the horizontal force **P** is applied to the roller at A. Determine the bar's initial angular acceleration and the acceleration of its top point B.



$$\overset{+}{\leftarrow} \Sigma F_x = m(a_G)_x; \qquad P = ma_G$$



$$\circlearrowleft + \Sigma M_G = I_G\alpha; \qquad P(\frac{L}{2}) = (\frac{1}{12}mL^2)\alpha$$

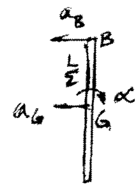
$$P = \frac{1}{6}mL\alpha$$

$$\alpha = \frac{6P}{mL} \qquad \textbf{Ans}$$

$$a_G = \frac{P}{m}$$

$$\mathbf{a}_B = \mathbf{a}_G + \mathbf{a}_{B/G}$$

$$-a_B\mathbf{i} = \frac{-P}{m}\mathbf{i} + \frac{L}{2}\alpha\,\mathbf{i}$$

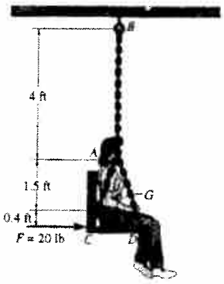


$$(\overset{+}{\leftarrow}) \qquad a_B = \frac{P}{m} - \frac{L\alpha}{2}$$

$$= \frac{P}{m} - \frac{L}{2}(\frac{6P}{mL})$$

$$a_B = -\frac{2P}{m} = \frac{2P}{m} \qquad \textbf{Ans}$$

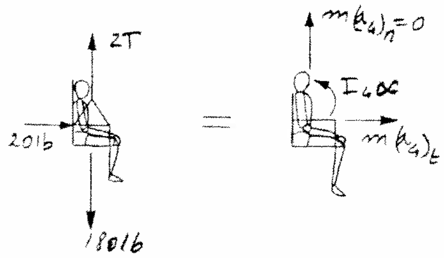
17-106. 67 A woman sits in a rigid position in the middle of the swing. The combined weight of the woman and swing is 180 lb and the radius of gyration about the center of mass G is $k_G = 2.5$ ft. If a man pushes on the swing with a horizontal force $F = 20$ lb as shown, determine the initial angular acceleration and the tension in each of the two supporting chains AB. During the motion, assume that the chain segment CAD remains rigid. The swing is originally at rest.



$\xrightarrow{+} \Sigma F_t = m(a_G)_t;\qquad 20 = \left(\frac{180}{32.2}\right)(a_G)_t$

$+\uparrow \Sigma F_n = m(a_G)_n;\qquad 2T - 180 = 0 \qquad (\omega = 0)$

$\circlearrowleft + \Sigma M_G = I_G\alpha;\qquad 20(0.4) = \left[\left(\frac{180}{32.2}\right)(2.5)^2\right]\alpha$



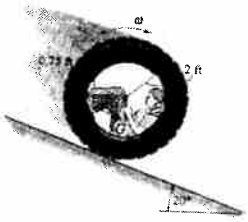
Solving,

$T = 90$ lb **Ans**

$\alpha = 0.229\ \text{rad/s}^2$ **Ans**

$(a_G)_t = 3.58\ \text{ft/s}^2$

17-107. A girl sits snugly inside a large tire such that both the girl and tire have a total weight of 185 lb, a center of mass at G, and a radius of gyration $k_G = 1.65$ ft about G. If the tire rolls freely down the incline, determine the normal and frictional forces it exerts on the ground when it is in the position shown and has an angular velocity of 6 rad/s. Assume that the tire does not slip as it rolls.



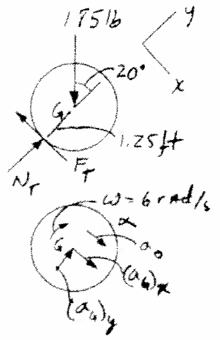
$+\nearrow \Sigma F_y = m(a_G)_y;\qquad N_T - 185\cos 20° = \left(\frac{185}{32.2}\right)(a_G)_y$

$+\searrow \Sigma F_x = m(a_G)_x;\qquad -F_T + 185\sin 20° = \left(\frac{185}{32.2}\right)(a_G)_x$

$\circlearrowleft + \Sigma M_G = I_G\alpha;\qquad F_T(1.25) = \left(\frac{185}{32.2}\right)(1.65)^2\alpha$

$\mathbf{a}_G = \mathbf{a}_O + \alpha \times \mathbf{r}_{G/O} - \omega^2 \mathbf{r}_{G/O}$

$(a_G)_x\mathbf{i} + (a_G)_y\mathbf{j} = 2\alpha\mathbf{i} + (-\alpha\mathbf{k}) \times (-0.75\mathbf{j}) - (6)^2(-0.75\mathbf{j})$



$(+\searrow)\qquad (a_G)_x = 1.25\alpha$

$(+\nearrow)\qquad (a_G)_y = 27\ \text{ft/s}^2$

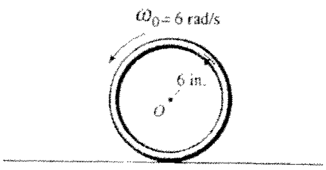
Thus,

$\alpha = 3.21\ \text{rad/s}^2$

$F_T = 40.2$ lb **Ans**

$N_T = 329$ lb **Ans**

***17-108.** The 10-lb hoop or thin ring is given an initial angular velocity of 6 rad/s when it is placed on the surface. If the coefficient of kinetic friction between the hoop and the surface is $\mu_k = 0.3$, determine the distance the hoop moves before it stops slipping.



$+\uparrow \Sigma F_y = m(a_G)_y$; $\quad N - 10 = 0 \qquad N = 10$ lb

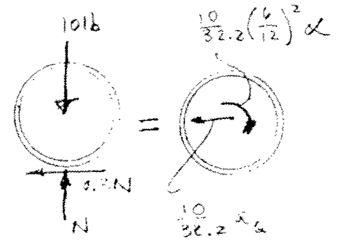
$\overset{+}{\leftarrow} \Sigma F_x = m(a_G)_x$; $\quad 0.3(10) = \left(\frac{10}{32.2}\right) a_G \qquad a_G = 9.66$ ft/s^2

$\circlearrowleft + \Sigma M_G = I_G \alpha$; $\quad 0.3(10)\left(\frac{6}{12}\right) = \left(\frac{10}{32.2}\right)\left(\frac{6}{12}\right)^2 \alpha \qquad \alpha = 19.32$ rad/s^2

When slipping ceases, $\quad v_G = \omega r = 0.5\omega \qquad [1]$

$(\circlearrowright +) \qquad \omega = \omega_0 + \alpha t$

$\omega = 6 + (-19.32)t \qquad [2]$



$(\overset{+}{\leftarrow}) \qquad v_G = (v_G)_0 + a_G t$

$v_G = 0 + 9.66t \qquad [3]$

Solving Eqs.[1] to [3] yields :

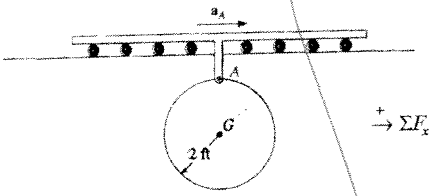
$t = 0.1553$ s $\qquad v_G = 1.5$ ft/s $\qquad \omega = 3$ rad/s

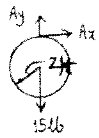
$(\overset{+}{\leftarrow}) \qquad s = s_0 + (v_G)_0 t + \frac{1}{2} a_G t^2$

$= 0 + 0 + \frac{1}{2}(9.66)(0.1553)^2$

$= 0.116$ ft $= 1.40$ in. $\qquad$ **Ans**

17-109. The 15-lb circular plate is suspended from a pin at A. If the pin is connected to a track which is given an acceleration $a_A = 3\ \text{ft/s}^2$, determine the horizontal and vertical components of reaction at A and the acceleration of the plate's mass center G. The plate is originally at rest.





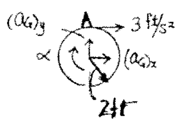
$$\xrightarrow{+} \Sigma F_x = m(a_G)_x; \qquad A_x = \frac{15}{32.2}(a_G)_x$$

$$+\uparrow \Sigma F_y = m(a_G)_y; \qquad A_y - 15 = \frac{15}{32.2}(a_G)_y$$

$$\circlearrowleft + \Sigma M_G = I_G\alpha; \qquad A_x(2) = [\frac{1}{2}(\frac{15}{32.2})(2)^2]\alpha$$

$$\mathbf{a}_G = \mathbf{a}_A + \mathbf{a}_{G/A}$$

$$\mathbf{a}_G = 3\mathbf{i} - 2\alpha\,\mathbf{i}$$



$$(+\uparrow) \qquad (a_G)_y = 0$$

$$(\xrightarrow{+}) \qquad (a_G)_x = 3 - 2\alpha$$

Thus,

$A_y = 15.0$ lb **Ans**

$A_x = 0.466$ lb **Ans**

$\alpha = 1\ \text{rad/s}^2$

$a_G = (a_G)_x = 1.00\ \text{ft/s}^2$ **Ans**

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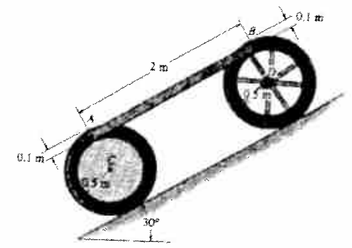
17-110. Wheel C has a mass of 60 kg and a radius of gyration of 0.4 m, whereas wheel D has a mass of 40 kg and a radius of gyration of 0.35 m. Determine the angular acceleration of each wheel at the instant shown. Neglect the mass of the link and assume that the assembly does not slip on the plane.



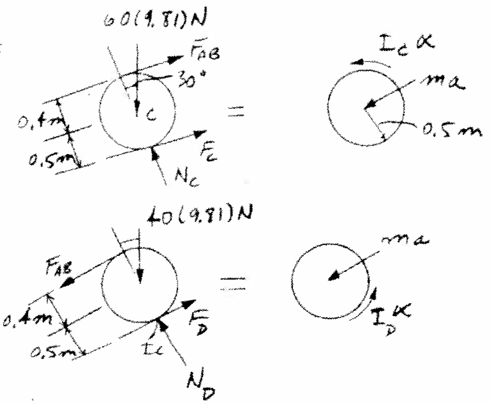
Each wheel has the same α.

Wheel C:

$\circlearrowleft + \Sigma M_{IC} = I_{IC}\alpha;\quad -F_{AB}(0.9) + 60(9.81)\sin 30°(0.5) = \left[60(0.4)^2 + 60(0.5)^2\right]\alpha$

Wheel D:

$\circlearrowleft + \Sigma M_{IC} = I_{IC}\alpha;\quad F_{AB}(0.9) + 40(9.81)\sin 30°(0.5) = \left[40(0.35)^2 + 40(0.5)^2\right]\alpha$

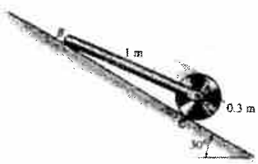


Solving,

$F_{AB} = -6.21$ N

$\alpha = 6.21$ rad/s^2 **Ans**

▪17-111. The assembly consists of an 8-kg disk and a 10-kg bar which is pin connected to the disk. If the system is released from rest, determine the angular acceleration of the disk. The coefficients of static and kinetic friction between the disk and the inclined plane are $\mu_s = 0.6$ and $\mu_k = 0.4$, respectively. Neglect friction at B.

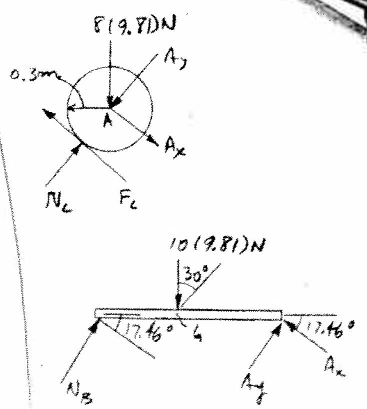


Disk:

$+\searrow \Sigma F_x = m(a_G)_x;\quad A_x - F_C + 8(9.81)\sin 30° = 8a_G \quad (1)$

$+\nearrow \Sigma F_y = m(a_G)_y;\quad N_C - A_y - 8(9.81)\cos 30° = 0 \quad (2)$

$\circlearrowleft \Sigma M_A = I_A\alpha;\quad F_C(0.3) = \left[\frac{1}{2}(8)(0.3)^2\right]\alpha \quad (3)$



Bar:

$+\searrow \Sigma F_x = m(a_G)_x;\quad 10(9.81)\sin 30° - A_x = 10a_G \quad (4)$

$+\nearrow \Sigma F_y = m(a_G)_y;\quad N_B + A_y - 10(9.81)\cos 30° = 0 \quad (5)$

$\circlearrowleft + \Sigma M_G = I_G\alpha;\quad -N_B(0.5\cos 17.46°) + A_x(0.5\sin 17.46°) + A_y(0.5\cos 17.46°) = 0 \quad (6)$

Assume no slipping of the disk,

$a_G = 0.3\alpha \quad (7)$

Solving, Eqs. (1)–(7),

$A_x = 8.92$ N, $A_y = 41.1$ N, $N_B = 43.9$ N

$a_G = 4.01$ m/s^2

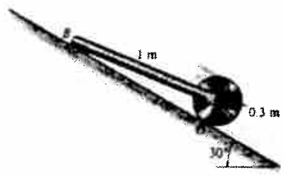
$\alpha = 13.4$ rad/s^2 **Ans**

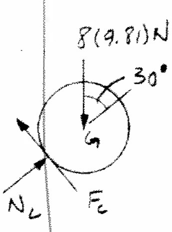
$N_C = 109$ N

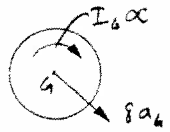
$F_C = 16.1$ N

$(F_C)_{max} = 0.6(109) = 65.4 \text{ N} > 16.1 \text{ N}$ OK

17-112. Solve Prob. 17-111 if the bar is removed. The coefficients of static and kinetic friction between the disk and inclined plane are $\mu_s = 0.15$ and $\mu_k = 0.1$, respectively.







$+\searrow \Sigma F_x = m(a_G)_x;$ $\quad 8(9.81)\sin 30° - F_C = 8a_G \quad (1)$

$+\nearrow \Sigma F_y = m(a_G)_y;$ $\quad -8(9.81)\cos 30° + N_C = 0 \quad (2)$

$\circlearrowleft + \Sigma M_G = I_G\alpha;$ $\quad F_C(0.3) = \left[\frac{1}{2}(8)(0.3)^2\right]\alpha \quad (3)$

Assume no slipping : $\quad a_G = 0.3\alpha$

Solving Eqs. (1) – (3) :

$N_C = 67.97$ N

$a_G = 3.27$ m/s^2

$\alpha = 10.9$ rad/s^2

$F_C = 13.08$ N

$(F_C)_{max} = 0.15(67.97) = 10.2 \text{ N} < 13.08 \text{ N}$ $\quad$ NG

Slipping occurs

$F_C = 0.1N_C$

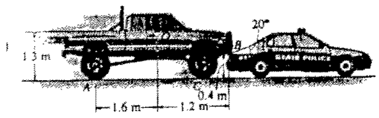
Solving Eqs. (1) – (3) :

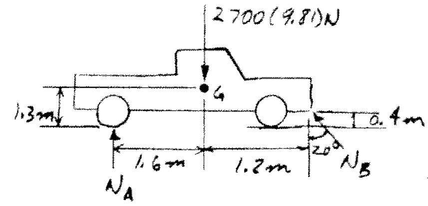
$N_C = 67.97$ N

$\alpha = 5.66$ rad/s^2 $\quad$ **Ans**

$a_G = 4.06$ m/s^2

17-113. A "lifted" truck can become a road hazard since the bumper is high enough to ride up a standard car in the event the car is rear-ended. As a model of this case consider the truck to have a mass of 2.70 Mg, a mass center G, and a radius of gyration about G of $k_G = 1.45$ m. Determine the horizontal and vertical components of acceleration of the mass center G, and the angular acceleration of the truck, at the moment its front wheels at C have just left the ground and its smooth front bumper begins to ride up the back of the stopped car so that point B has a velocity of $v_B = 8$ m/s at 20° from the horizontal. Assume the wheels are free to roll, and neglect the size of the wheels and the deformation of the material.

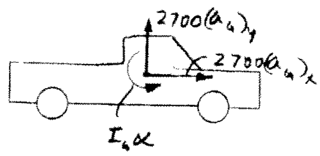




$\xrightarrow{+} \Sigma F_x = m(a_G)_x;\qquad -N_B\sin 20° = 2700(a_G)_x \qquad (1)$

$+\uparrow \Sigma F_y = m(a_G)_y;\qquad N_A + N_B\cos 20° - 2700(9.81) = 2700(a_G)_y \qquad (2)$

$\circlearrowleft + \Sigma M_G = I_G\alpha;\qquad N_B\cos 20°(1.2) - N_B\sin 20°(0.9) - N_A(1.6) = 2700(1.45)^2\alpha \qquad (3)$



$\mathbf{v}_A = \mathbf{v}_B + \mathbf{v}_{A/B}$

$v_A\mathbf{i} = 8\cos 20°\mathbf{i} + 8\sin 20°\mathbf{j} + (\omega\mathbf{k})\times(-2.8\mathbf{i} - 0.4\mathbf{j})$

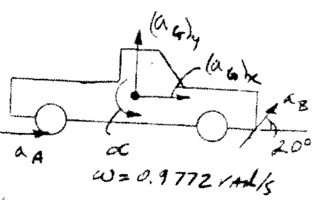
$(+\uparrow)\qquad 0 = 0 + 8\sin 20° - 2.8\omega$

$\omega = 0.9772$ rad/s

$\mathbf{a}_A = \mathbf{a}_G + \alpha\times\mathbf{r}_{A/G} - \omega^2\mathbf{r}_{A/G}$

$a_A\mathbf{i} = (a_G)_x\mathbf{i} + (a_G)_y\mathbf{j} + \alpha\mathbf{k}\times(-1.6\mathbf{i} - 1.3\mathbf{j}) - (0.9772)^2(-1.6\mathbf{i} - 1.3\mathbf{j})$

$(+\uparrow)\qquad 0 = 0 + (a_G)_y - 1.6\alpha + 1.2414 \qquad (4)$



$\mathbf{a}_B = \mathbf{a}_G + \alpha\times\mathbf{r}_{B/G} - \omega^2\mathbf{r}_{B/G}$

$a_B\cos 20°\mathbf{i} + a_B\sin 20°\mathbf{j} = (a_G)_x\mathbf{i} + (a_G)_y\mathbf{j} + \alpha\mathbf{k}\times(1.2\mathbf{i} - 0.9\mathbf{j}) - (0.9772)^2(1.2\mathbf{i} - 0.9\mathbf{j})$

$a_B\cos 20° = (a_G)_x + 0.9\alpha - 1.1459$

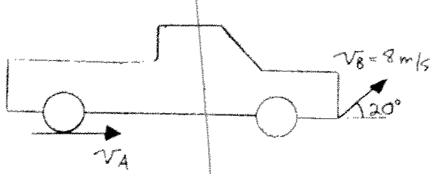
$a_B\sin 20° = (a_G)_y + 1.2\alpha + 0.85943$

or,

$1.0642(a_G)_x - 2.924(a_G)_y - 2.5508\alpha = 0 \qquad (5)$

Solving Eqs (1)–(5),

$N_A = 8.38$ kN $\qquad N_B = 14.4$ kN



$(a_G)_x = -1.82\ \text{m/s}^2 = 1.82\ \text{m/s}^2 \leftarrow$ **Ans**

$(a_G)_y = -1.69\ \text{m/s}^2 = 1.69\ \text{m/s}^2 \downarrow$ **Ans**

$\alpha = -0.283\ \text{rad/s}^2 = 0.283\ \text{rad/s}^2$ **Ans**