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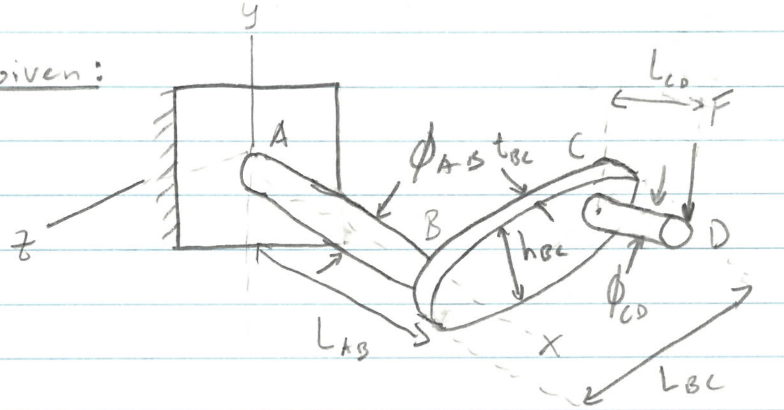
Machine elements HW 1 January 19, 2020

1. Given:



Knowns: $L_{AB} = 5$ in $\quad F = 300$ lbs

$L_{BC} = 4$ in

$L_{CD} = 1.5$ in

$\phi_{AB} = .75$ in

$\phi_{CD} = .5$ in

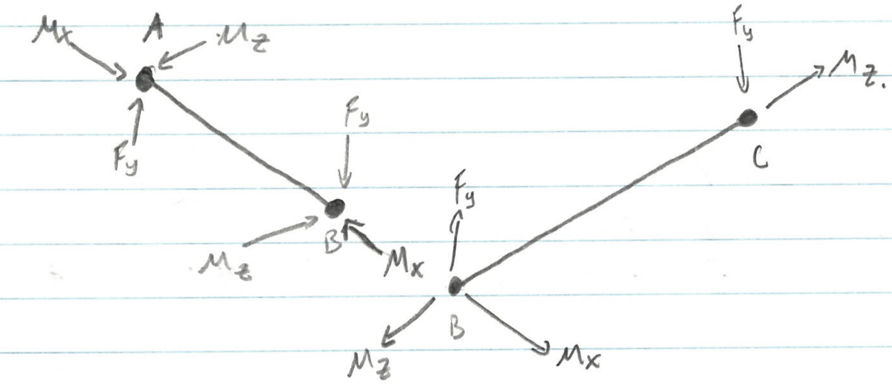
$t_{BC} = .25$ in

$h_{BC} = 1.25$ in

Find: a. Free body Diagram of Shaft AB / arm BC. (in isolation)

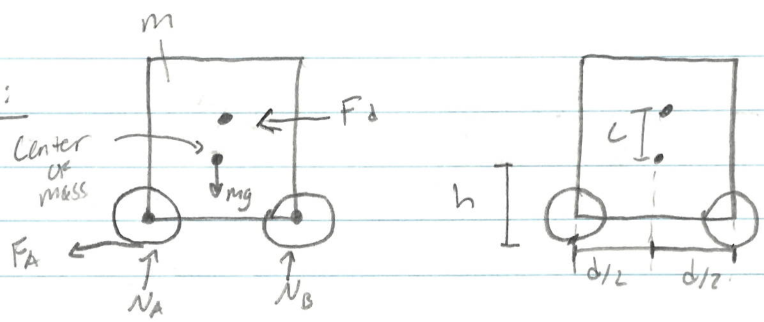
b. Magnitude of all Forces / moments acting on the Ends of these members

Solution: a.



B.
$$F_y^A = F_y^B = F_y^C = F = 300 \text{ lbs}$$
$$M_z^C = M_z^B = F(L_{CD}) = (300 \text{ lbs})(1.5 \text{ in}) = 450 \text{ lb}\cdot\text{in}$$
$$M_x^B = M_x^A = F(L_{BC}) = (300 \text{ lbs})(4 \text{ in}) = 1200 \text{ lb}\cdot\text{in}$$
$$M_z^A = F(L_{AB} + L_{CD}) = (300 \text{ lbs})(5 \text{ in} + 1.5 \text{ in}) = 1950 \text{ lb}\cdot\text{in}$$

3. Given:



Knowns: none

Solution:

a. $\Sigma F_y = N_A + N_B - mg = 0$

$\Sigma F_x = -F_d - F_A = ma_x$

$\Sigma M_c = (F_d)(c) - F_A(h) - N_A\left(\frac{d}{2}\right) + N_B\left(\frac{d}{2}\right) = 0$

b. $N_B = mg - N_A$

$N_A\left(\frac{d}{2}\right) = (F_d)(c) + (N_B)\left(\frac{d}{2}\right) - F_A(h)$

$N_A = \frac{2}{d}\left(F_d(c) - F_A h\right) + N_B$

$N_A = \frac{2}{d}\left(F_d c - F_A h\right) + mg - N_A$

$2N_A = 2/d\,(F_d c - F_A h) + mg$

$$\boxed{N_A = \frac{F_d c - F_A h}{d} + \frac{1}{2}mg}$$

c. $N_B = mg - \left(\frac{F_d c - F_A h}{d} + \frac{1}{2}mg\right)$

$N_B = mg - \frac{F_d c}{d} + \frac{F_A h}{d} - \frac{1}{2}mg$

$$\boxed{N_B = \frac{1}{2}mg - \frac{F_d c}{d} + \frac{F_A h}{d}}$$

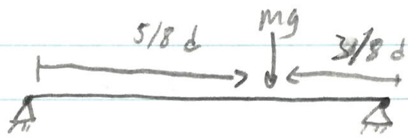
d. As you Break and add in the F_A term, more weight will move to the front of the scooter since F_A is positive in the equation for N_B.

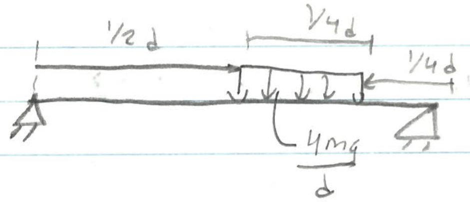
e. F_A is max when $N_A = 0$

$0 = F_d c - F_A h + \frac{1}{2}mg\,d$

$$\boxed{F_A = \frac{F_d c + \frac{1}{2}mgd}{h}}$$

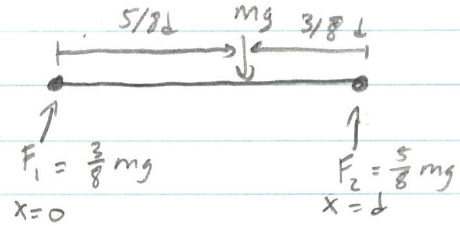
5. Given:

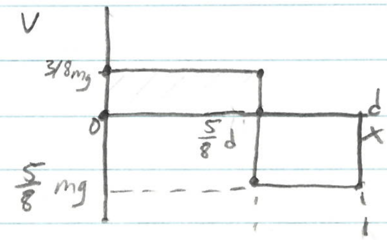




Knowns: none

Solution: a.



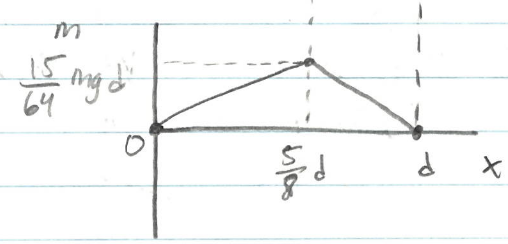


$$\Sigma M_{x=0} = F_2 d - mg\left(\frac{5}{8}d\right) = 0$$

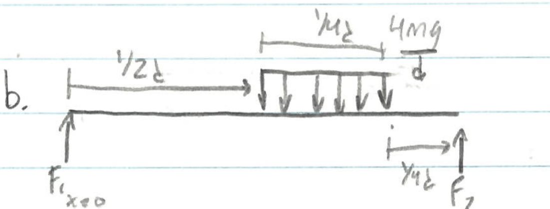
$$F_2 = \frac{5}{8} mg$$

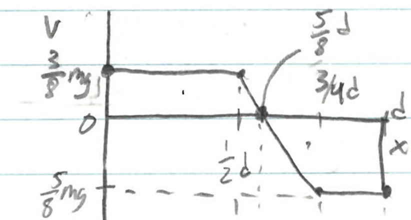
$$\Sigma F_y = F_1 + F_2 - mg = 0$$

$$F_1 = 3/8\, mg$$



b.



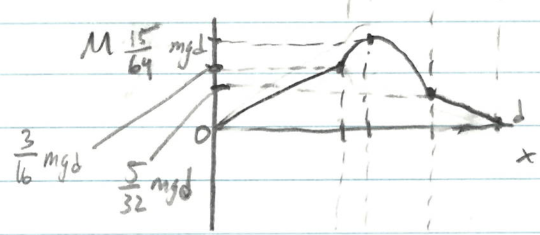


$$\Sigma M_{x=0} = F_2 d - \frac{4mg}{d}\left(\frac{1}{4}d\right)\left(\frac{5}{8}d\right) = 0$$

$$F_2 = \frac{5}{8} mg$$

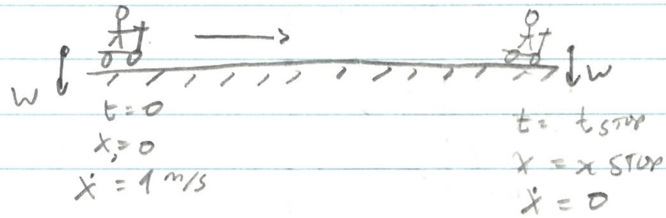
$$F_1 = 3/8\, mg$$

$\frac{3}{16}mgd$



c. The maximum bending moments for part A/B is 15/64 mgd. They are equal because even though one is a point load and the other is a distributed load, the total force coming down is still the same.

4. Given:



Knowns: W = 180 lbs.

$\dot{x} = 9$ m/s

@ x = 0 / t = 0 Scooter breaks w/ constant a = −.3g until it stops.

Solution:

a. $\ddot{x} = -.3g = -2.943\ m/s^2$

$t = \left|\frac{\dot{x}}{\ddot{x}}\right| = \left(\frac{9\ m/s}{-2.943}\right) = \boxed{3.05\ \text{sec.}}$

b. $X = X_0 + Vt + \frac{1}{2}at = \overset{m/s}{9}(\overset{sec}{3.05}) - \frac{1}{2}(2.943\ m/s)(3.05)^2$

$\boxed{X = 13.76\ m}$

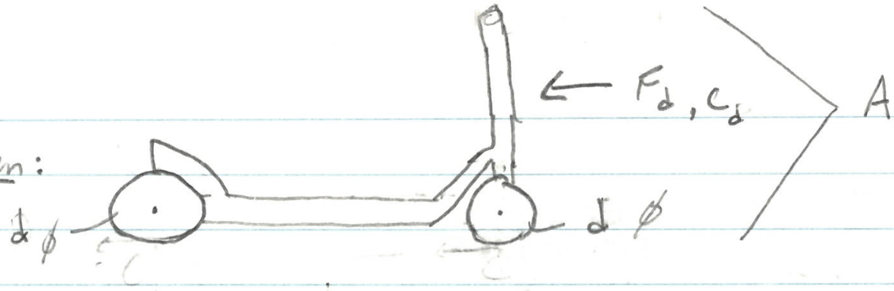
c. $180\ \text{lbs} \cdot \frac{4.4822\ N}{1\ \text{lbs}} = 800\ N$

$W = F \cdot d = mad = \frac{F}{g}ad = \left(\frac{800\ N}{9.81\ m/s^2}\right)(2.943\ m/s^2)(13.76\ m)$

$\boxed{W = 3.3\ KJ.}$

D. $P = \frac{W}{t} = \frac{3.3\ KJ}{3.05\ s} = \boxed{1082\ W}$

2. Given:



Knowns: $F_d = \frac{1}{2} C_d A \rho V^2 = K_A V^2$

$K_A = 0.3$ kg/m

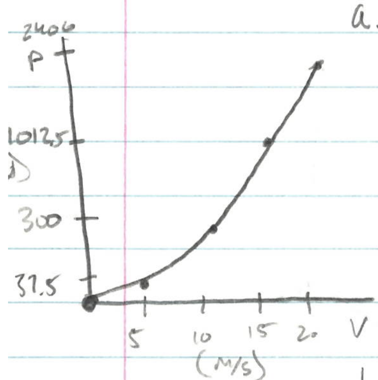
$d\phi = 8$ in $=$

Part b. Voltage = 24v

$\omega = 5500$ rev/min

$T = 1.736$ N.m

Solution:



a. $P = FV = K_A V^2 \cdot V = K_A V^3$

$P(0\ m/s) = (0.3\ kg/m)(0\ m/s)^3 = 0$ W

$P(5\ m/s) = (0.3\ kg/m)(5\ m/s)^3 = 37.5$ W

$P(10\ m/s) = (0.3\ kg/m)(10\ m/s)^3 = 300$ W

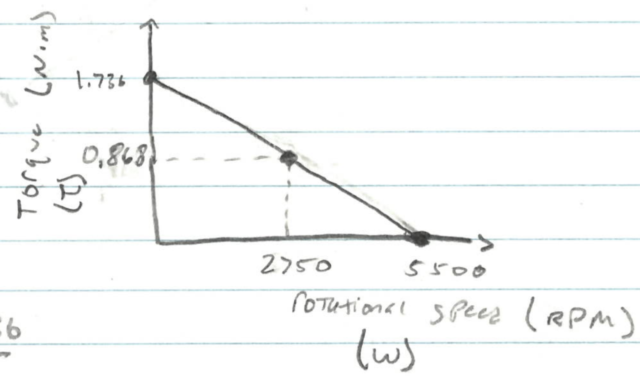
$P(15\ m/s) = (0.3\ kg/m)(15\ m/s)^3 = 1012.5$ W

$P(20\ m/s) = (0.3\ kg/m)(20\ m/s)^3 = 2400$ W

b. $V = 24$ V

$\omega = 5500$ rev/min

$T = 1.736$ N.m



$P = T \cdot \omega$ Slope $= \dfrac{.868 - 1.736}{2750 - 0}$

$= -3.156 \cdot 10^{-4}$

$\dfrac{rev}{min} \cdot \dfrac{2\pi\ rad}{1\ rev} \cdot \dfrac{1\ min}{60\ sec}$

$P = (-3.156 \cdot 10^{-4} n^2 + 1.736)(0.1047 n)$

$P_{max} = \dfrac{dP}{dn} = -6.61 \cdot 10^{-5} n + 0.182 = 0$

$n = 2750$

$P_{max} = -3.156 \cdot 10^{-5} (2750)^2 + .182(2750)$

$P_{max} = 261$ W

$P = K_A V^3 \qquad V = \sqrt[3]{\dfrac{P}{K_A}} = 9.55$ m/s

* Rest of problem on last page.

c. ϕ wheel = 8 in = .1016 m $\qquad V_{max\ wheel} = 9.55$ m/s $\quad V = \omega r$

$\omega_{motor} = 2750$ RPM

$\omega_m r_m = \omega_w r_w = \left(\dfrac{V_w}{r_w}\right)\left(\dfrac{60\ s}{min} \cdot \dfrac{1\ rev}{2\pi\ rad}\right)(r_w)$

Gear ratio: $\dfrac{2750\ rpm}{897.6} \approx 3.06$

*

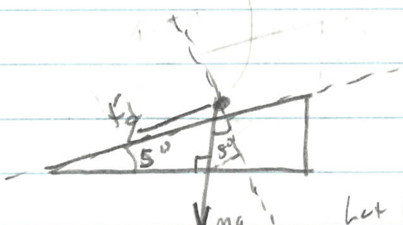
2C. $\phi_{wheel} = 8in \rightarrow .2032\ m$ $\quad V_{max\ wheel} = 9.55\ m/s$ $\quad V = \omega r$

$\omega_{motor} = 2750\ RPM$

$$\omega_M r_m = \omega_w r_w = \frac{V_w}{\cancel{r_w}} \cdot \frac{60\ sec}{1\ min} \cdot \frac{1\ rev}{2\pi\ rad} \cdot \cancel{r_w}$$

$$\text{Gear ratio} = \frac{\omega_M}{\omega_w} = \frac{2750}{V_w \cdot 60 \cdot 2\pi} = \boxed{3.06}$$

2.D.



$P = F_{net}V = (F_d + F_w)V = K_A V^3 + F_w V$

$P = (.3)(9.55)^3 + W\ \cancel{\cos 5°}\ \sin 5° (9.55)$

Let W = 66kg P =

$P = 316.22\ W$

$\Delta P\ 55.23\ W$

$\Delta P = FV = mg \sin 5° (9.55)$

$\boxed{\text{additional power} = 9.55\ mg \sin 5°}$