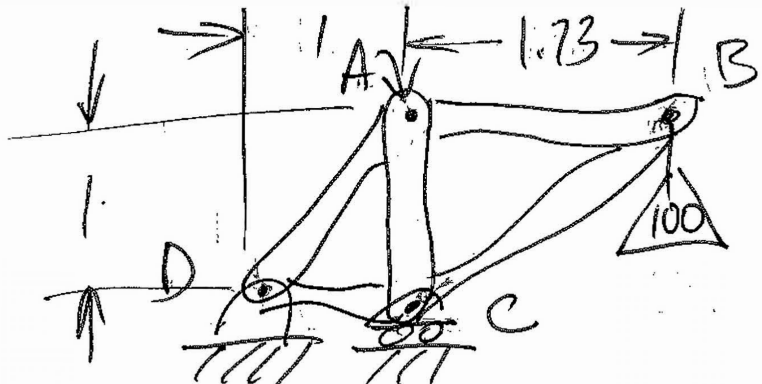
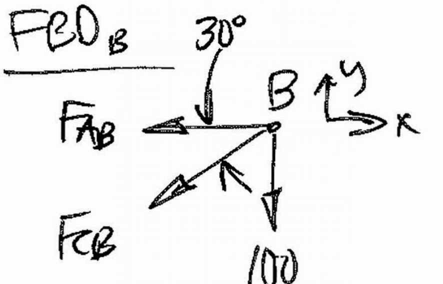
RBE 1001 Homework 1 **Name:** Solution

DRAW APPROPRIATE, COMPLETE <u>FBDs</u> AND USE THE APPROPRIATE <u>EofE</u> IN SOLVING THESE PROBLEMS.

1) For the "pin-jointed", strut-supported robot arm below, calculate the forces in each of the "2-force" struts (AB, BC, CD, AC, AD). Assume the pin D is rigidly attached to the robot chassis and that pin C is constrained to the chassis by a no-friction roller joint. Solve using FBD/EofE analysis of individual pin joints or overall structure as appropriate. (~ ans: F_{AB} = 170N Tension; F_{AD} = 250N Tension, etc.)





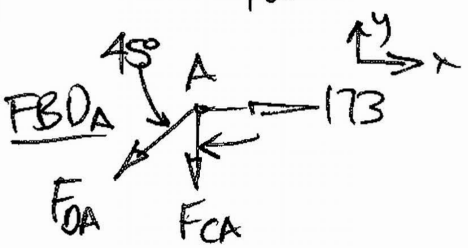
EofE

$\Sigma F_y = 0 = -100 - F_{CB}\sin 30$

$\therefore F_{CB} = \frac{-100}{.5} = \boxed{-200N\ (comp)}$

$\Sigma F_x = 0 = -F_{AB} - F_{CB}\cos 30$

$\therefore F_{AB} = 200(.866) = \boxed{173\ (tens)}$



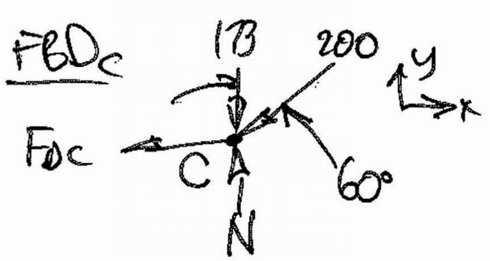
EofE

$\Sigma F_x = 0 = 173 - F_{DA}\sin 45$

$\therefore F_{DA} = \frac{173}{.707} = \boxed{245N\ (tens)}$

$\Sigma F_y = 0 = -F_{CA} - F_{DA}\cos 45$

$\therefore F_{CA} = -245(.707) = \boxed{-173N\ (comp)}$



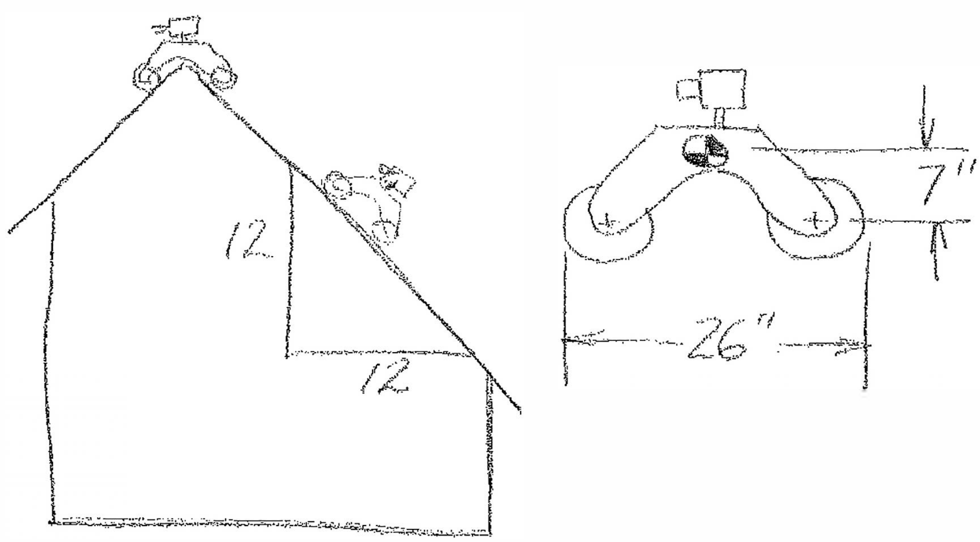
EofE

$\Sigma F_x = 0 = -200\sin 60 - F_{DC}$

$\therefore F_{DC} = -200(.866) = \boxed{-173N\ comp}$

Problem statement (Questions 2-4):

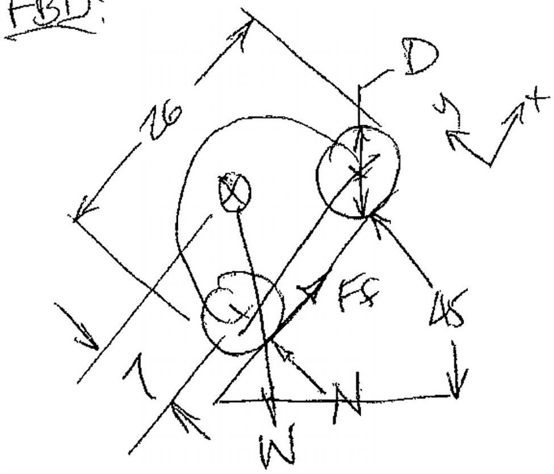
A 4-wheel drive robot is required to inspect a roof for damage. It must be able to maneuver up and over a roof pitch of 12:12 (this means the roof rises 12 inches for every 12 inches on the horizontal). For packing and maneuverability purposes, the maximum overall length dimension is 26 inches. The CG of the robot is centered fore and aft (and left and right) and is located 7 inches above the axle centerlines. For practical surface considerations, larger diameter wheels are better than smaller ones (all 4 wheels must be identical as the robot must be symmetrical fore and aft).



2) What are the largest possible diameter wheels that will just allow the robot to be statically stable on a 12:12 pitch? (~ans: D_{wh} = 5in)

implies zero normal force on upper wheels

FBD:



EofE:

$$\Sigma F_y = 0 = N - W\cos 45°$$

$$\therefore N = .707W$$

$$\Sigma F_x = 0 = F_f - W\sin 45°$$

$$\therefore F_f = .707W$$

$$\Sigma M_{z_\otimes} = 0 = F_f\left(7+\frac{D}{2}\right) - N\left(\frac{26}{2}-\frac{D}{2}\right)$$

$$\therefore 7+\frac{D}{2} = 13-\frac{D}{2}$$

$$\boxed{D=6in}$$

3) What is the minimum coefficient of friction required between the wheel tread and the roof material? (~ans: $\mu = 0.9$)

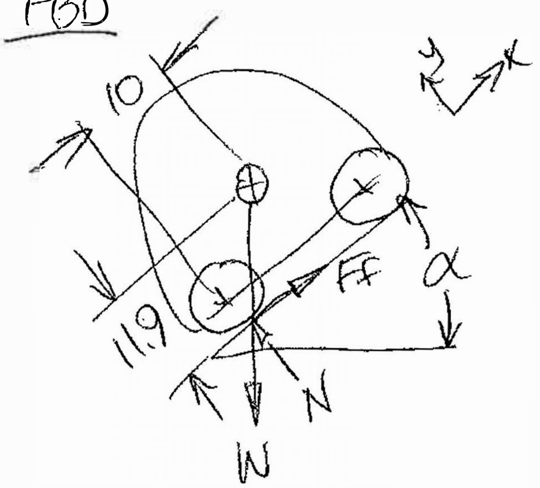
from FBD_{Prob2} : $N = .707W; \; F_f = .707W$

from Physics : $F_f \leq \mu N$

$\therefore \mu \geq \frac{F_f}{N} \boxed{\geq 1.0}$

4) As the robot developed, additional sensors were added to the top structure. The resulting CG is now 1.9 inches higher than as planned. Given the wheels established in 1) above, what is max grade (in degrees from horizontal) for static stability? (~ans: $\alpha = 30°$)

FBD



E of E

$\Sigma F_x = 0 = F_f - w\sin\alpha$

$\therefore F_f = w\sin\alpha$

$\Sigma F_y = 0 = N - w\cos\alpha$

$\therefore N = w\cos\alpha$

$\Sigma M_{z_{\oplus}} = 0 = F_f(11.9) - N(10)$

$\therefore w\sin\alpha(11.9) = w\cos\alpha(10)$

$\div$ by $w\cos\alpha$

$\tan\alpha(11.9) = 10$

$\alpha = \tan^{-1}\left(\frac{10}{11.9}\right) = \boxed{40°}$