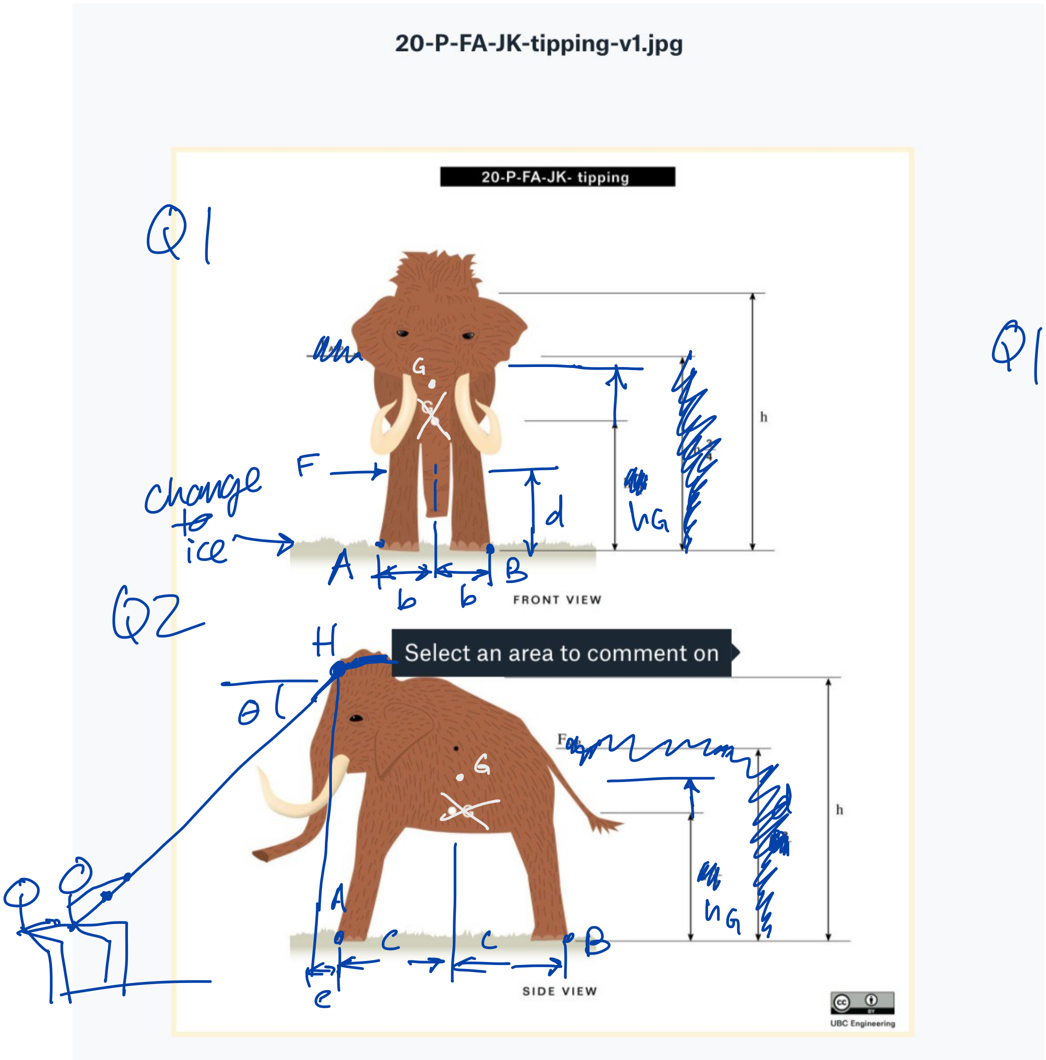
20-P-FA-JK-tipping-v1



Mammoth dimensions

$h = 3.75\,m$
(range $3.00-4.25\,m$)

$h_G = 0.55h$

$m = 6000\,kg$ (4000-8000)

$b = 0.8\,m$

$F = 400\,N$ (high, for human)

$c = 1.5\,m$, $e = 0.3$

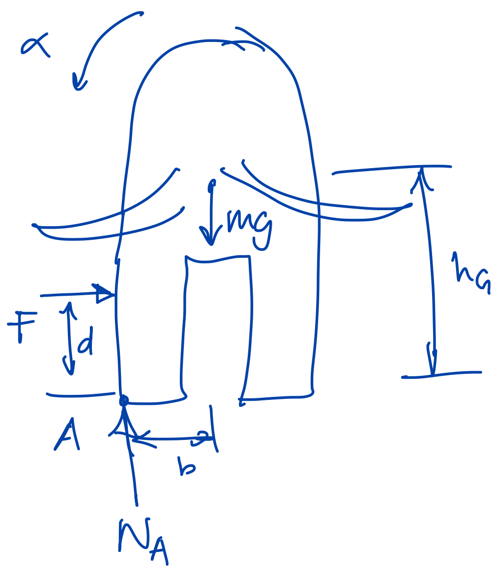
Q1: You wish to move a mammoth that is blocking your path. The mammoth is standing on ice. You do not want the mammoth to topple over on top of you and crush you.

(a) If you can apply shove the mammoth at a height $d = 1.2\,m$ from the ground, how much force, F, will it take to tip the mammoth?

(b) If you can produce a maximum of 400N in a shove force, are you in danger of tipping the mammoth on top of you? (Y/N)

(c) If you apply 400N, what acceleration will the mammoth have?

SOLUTION



Just at edge of tipping:

- normal force @ A
- $\alpha = 0$, $a_{Gy} = 0$

$$\Sigma F_x : F = m a_{Gx}$$

$$\Sigma F_y : N_A - mg = 0$$

$$\Sigma M_A : -F \cdot d - mgb = -m a_{Gx} h_G$$

$$\Sigma M_A \Rightarrow +Fd + mgb = +F h_G$$

$$F(h_G - d) = mgb$$

$$F = \frac{mgb}{(h_G - d)} = \frac{(6000\,kg)(9.81\,m/s^2)(0.8\,m)}{(0.55(3.75) - 1.2)}$$

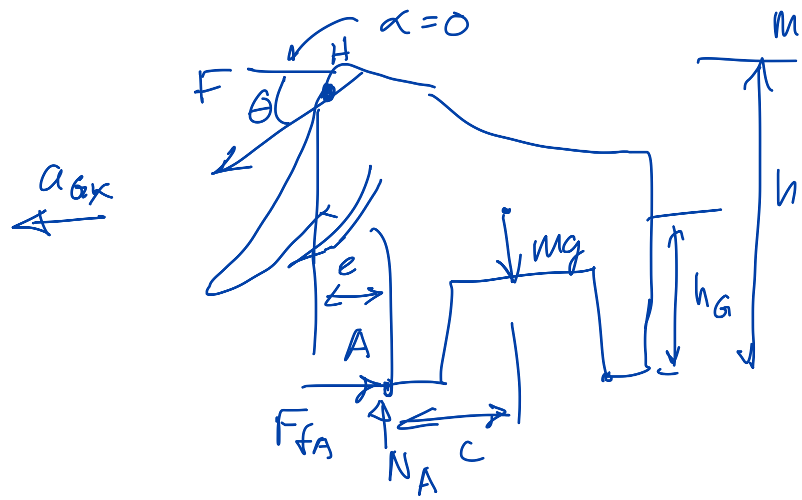
$$= \underline{\underline{54594\ N}}$$

(b) In danger of being crushed? $\underline{\text{NO}}$ (eqn: $F \leq 400$ = yes, $F > 400$ = no)

(c) $F = m a_{Gx}$

$$a_{Gx} = \frac{F}{m} = \frac{400\,N}{6000\,kg} = \underline{\underline{0.067\ m/s^2}}$$

Q2: You want to tip that mammoth! You and your friends manage to lasso the mammoth around the top of it's head. If each person can apply 400 N to pulling on the mammoth, how many people will you need to tip the mammoth? $\theta = 30°$ The ground is rough (no slipping)



minimum for tipping:

- $\alpha = 0$, $a_{Gx} = 0$
- Normal force @ A

no slipping

- $a_{Gy} = 0$

$\Sigma F_x: -F\cos\theta + F_{fA} = 0$

$\Sigma F_y: N_A - mg = 0$

$\Sigma M_A: \vec{r}_{H/A} \times \vec{F} - mgc = 0$

$\vec{r}_{H/A} = -e\hat{i} + h\hat{j}$

$\vec{F} = -F\cos\theta\hat{i} - F\sin\theta\hat{j}$

$\vec{r}_{H/A} \times \vec{F} = (eF\sin\theta + hF\cos\theta)\hat{k}$

$\Rightarrow eF\sin\theta + hF\cos\theta - mgc = 0$

$F(e\sin\theta + h\cos\theta) = mgc$

$F = \dfrac{mgc}{(e\sin\theta + h\cos\theta)} = \dfrac{6000\,\text{kg}(9.81\,\text{m/s}^2)(1.5\,\text{m})}{(0.3\sin 30 + 3.75\cos 30)}$

$= \dfrac{88290}{3.398} = 25982.9\ \text{N}$

400 N per person: $n = \dfrac{25982.9\,\text{N}}{400\,\text{N}} = 64.957$ round up $=$ 65 people.