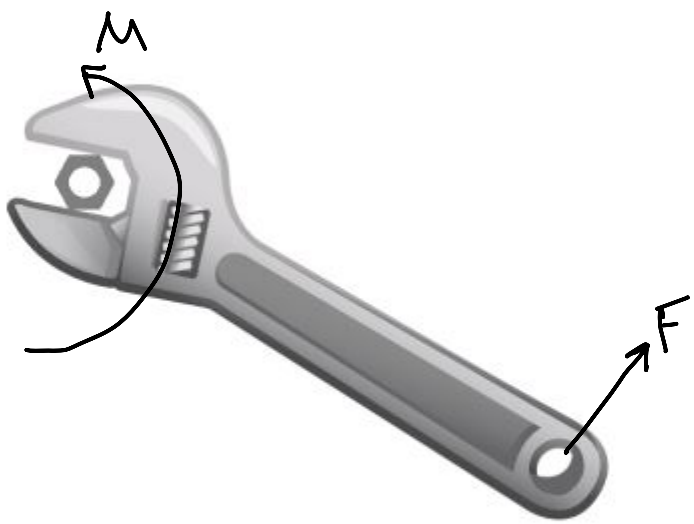
Name: ______________
Group members: ____________________ ____________________ ____________________

TAM 210/211 - Worksheet 5

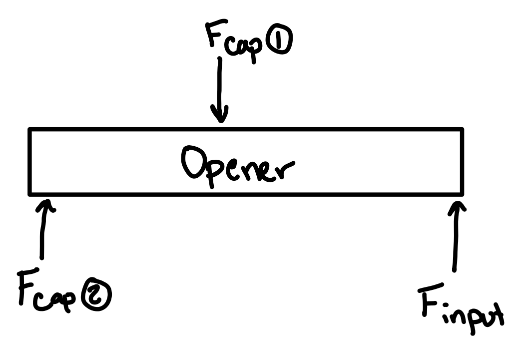
Objectives:

- Evaluate moments in 2D and 3D problems
- Obtain resultant forces and moments for equivalent systems.

1) Draw the forces and resulting moment that acts on a wrench when unfastening a nut.

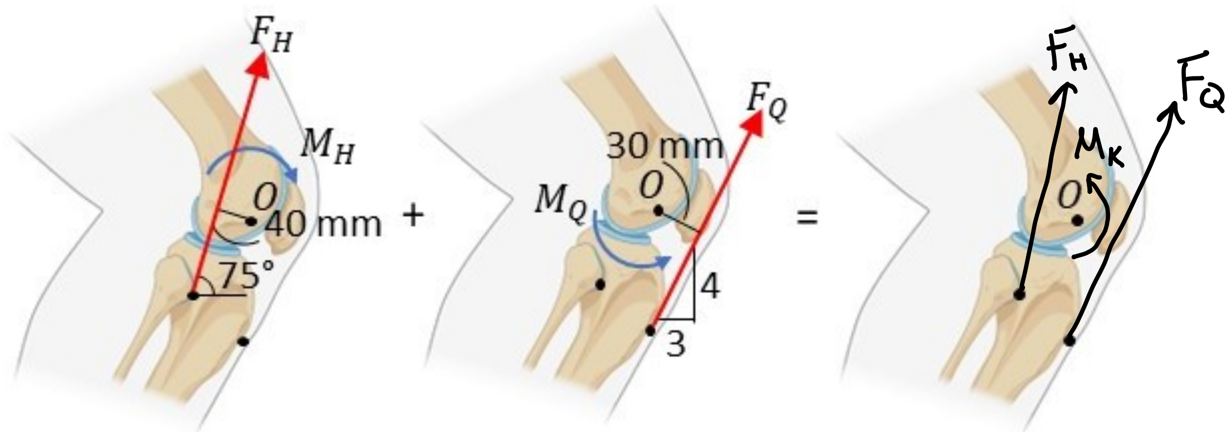


2) Sketch a diagram of the forces and moments acting on the bottle opener?



3) A rotational moment in the knee is generated by the force from the hamstrings (F_H) and the force from the quadriceps (F_Q). The diagram for each muscle is given separately.

a) On the blank knee diagram, draw the forces and resulting moment that acts on the knee when it is in a flexed position.



b) The force generated by the hamstrings and the quadriceps are 845 N and 1500 N, respectively. Using Figure in part a, determine the moment of the force about point O using the scalar formulation.

$$M_H = 850(40) = 33{,}800 \text{ N-mm}$$

$$M_Q = 1500(30) = 45{,}000 \text{ N-mm}$$

$$\Sigma M_K = M_Q - M_H = 11{,}200 \text{ N-mm} \quad \boxed{11.2 \text{ N-m}}$$

c) Using Figure in problem 3.i, determine (i) the $< i, j, k >$ components of F_H and F_Q, (ii) the moment of the force about point O using the vector formulation, and (iii) the moment of the same force about the x-axis. (iv) Is the knee flexing or extending?

i) $F_H = 219\hat{i} + 816\hat{j} + 0\hat{k}$

$F_Q = 900\hat{i} + 1200\hat{j} + 0\hat{k}$

ii) $r_H = 38.6\hat{i} + 10.35\hat{j} + 0\hat{k}$

$r_Q = 18\hat{i} + 24\hat{j} + 0\hat{k}$

$$M_H = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -38.6 & 10.35 & 0 \\ 219 & 816 & 0 \end{vmatrix}$$

$= (0-0)\hat{i} - (0-0)\hat{j} + (-38.6 \cdot 816 - 10.35 \cdot 219)\hat{k}$

$= \langle 0, 0, -33764 \rangle$ N-mm $\quad \langle 0, 0, -33.8 \rangle$ N-m

$$M_Q = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 24 & -18 & 0 \\ 900 & 1200 & 0 \end{vmatrix}$$

$= (0-0)\hat{i} - (0-0)\hat{j} + (24 \cdot 1200 + 18 \cdot 900)\hat{k}$

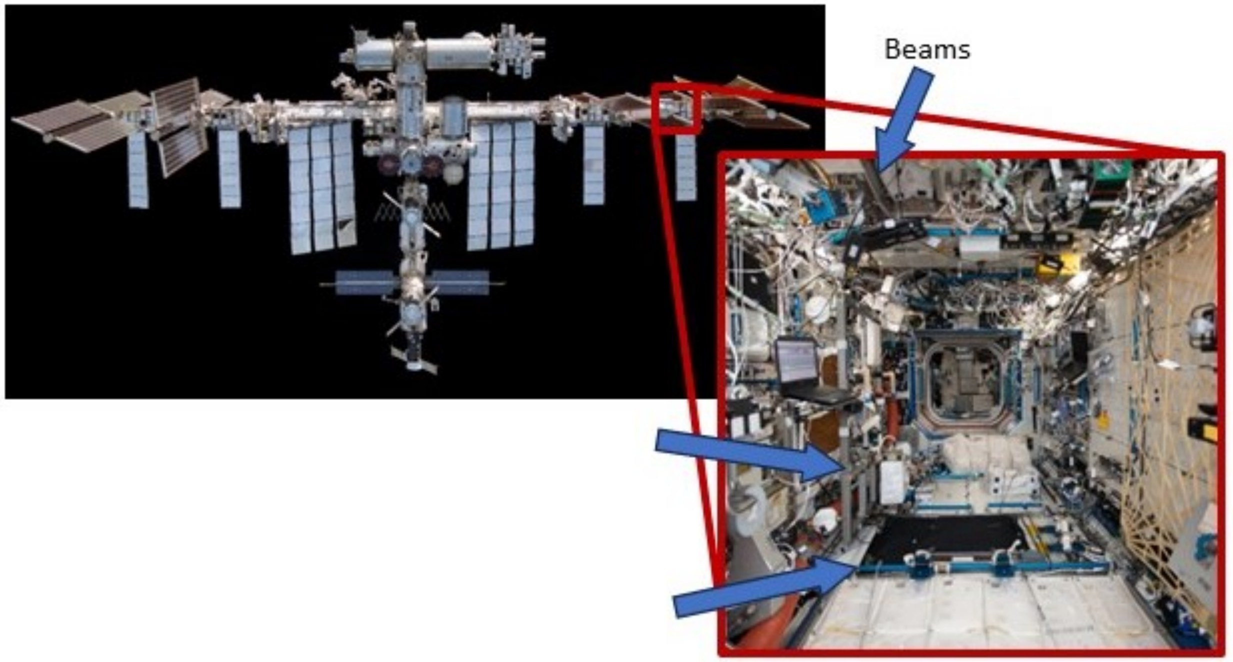
$= \langle 0, 0, 45000 \rangle$ N-mm $\quad \langle 0, 0, 45.0 \rangle$ N-m

$\Sigma M_K = 45 - 33.8 = \boxed{11.2 \text{ N-m}}$

iii) $0\hat{i}$

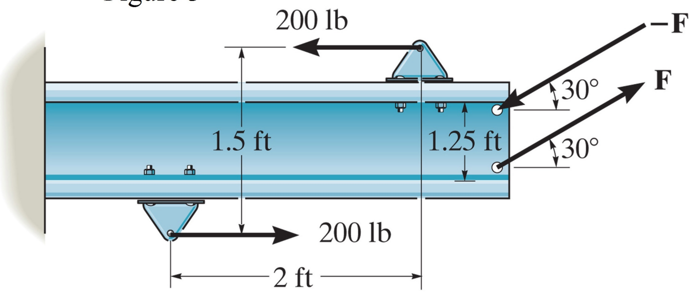
iv) Extending

Rotational moments are often seen in beam applications. The following examples are of beams that could be found on a space station!



4) Using Figure 3, determine the magnitude of F so that the resultant couple moment is 600 lb.ft counterclockwise. Where on the beam does the resultant couple moment act?

Figure 3



vector way:

$$\sum \vec{M} = [0,0,-600] = (\vec{r}_1 \times \vec{F}_1) + (\vec{r}_2 \times \vec{F}_2)$$

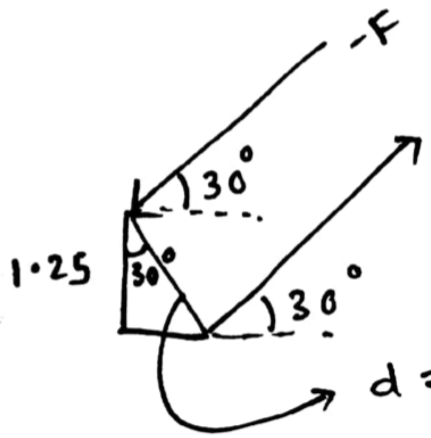
with $\vec{F}_1 = [200,0,0]$ and $\vec{F}_2 = [F\cos 30°, F\sin 30°, 0]$

$\vec{r}_1$ = any position vector from line of action of F_1 that is the 200 lb force

$\vec{r}_2$ = " " for F_2 that is the unknown $\vec{F}$

$$[0,0,-600] = [0,1.5,0] \times [200,0,0] + [0,1.25,0] \times [F\cos 30°, F\sin 30°, 0]$$

$F = 277.1281$ N



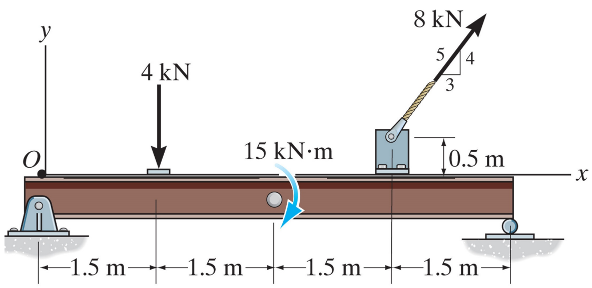
$\rightarrow \quad \sum M = 600 = 200(1{\cdot}5) + F(1{\cdot}25\cos 30°)$

$\Rightarrow \quad F = 277.128$ lb

$d = 1{\cdot}25\cos 30°$

→ Resultant couple moment can act anywhere on the beam.

5) Replace the force system acting on the beam in Figure 4 by: (a) an equivalent force and couple moment at point O, and (b) an equivalent force distance x to the right of O. Sketch your equivalent system on the right side of Figure 4.



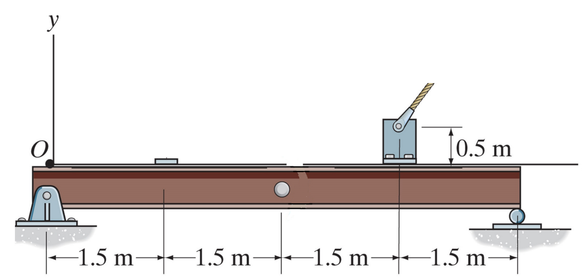


Figure 4

a) $\sum F_x = 8 \times \left(\frac{3}{5}\right) = 4.8 \text{ KN}$

$\sum F_y = 8 \times (4/5) - 4 = 2.4 \text{ KN}$

$\sum M_o = -15 - 4(1.5) - (4.8 \times 0.5) + (\overset{6.4}{\cancel{2.4}} \times 4.5) = 5.4 \text{ KN-m}$

$\Rightarrow \quad F_R = \langle 4.8, 2.4, 0 \rangle \text{ KN} \quad \Rightarrow \boxed{|F_R| = 5.37 \text{ KN}}$

$\boxed{M_R = 5.4 \text{ KN-m}}$

b) $\vec{M_R} = \vec{r} \times \vec{F} = (x, 0, 0) \times (4.8, 2.4, 0)$

$\Rightarrow \quad 5.4 = 2.4 x$

$\Rightarrow \quad \boxed{x = 2.25 \text{ m}}$