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IE #1 Mechanics.

exercise 1).

I certify that I will not cheat, and I will follow the guidelines given in the subject, I will not chat with anyone else than the teacher supervising the exam.

1) $\vec{dF} = \vec{dP} + \vec{dT}$

1.1) $\vec{S} = \int \vec{dF} = \int \vec{dP} + \int \vec{dT} = \frac{1}{2} \rho l \omega^2 C_z \int_{S_2} r^2 dr \, \vec{z_{1,2}}$

$r \in [0, L]$.
$$- \frac{1}{2} \rho l \omega^2 C_4 \int_{S_2} r^2 dr \, \vec{y_2}.$$

$$\vec{S} = \frac{1}{2} \rho l \omega^2 C_z \left[\frac{r^3}{3}\right]_0^L \vec{z_{1,2}} - \frac{1}{2} \rho l \omega^2 C_4 \left[\frac{r^3}{3}\right]_0^L \vec{y_2}$$

$$\vec{S} = \frac{1}{2} \rho l \omega^2 C_z \frac{L^3}{3} \vec{z_{1,2}} - \frac{1}{2} \rho l \omega^2 C_4 \frac{L^3}{3} \vec{y_2}.$$

$$\vec{M_F(O)} = \int_0^L \vec{OM} \wedge \vec{dF} = \int_0^L \vec{OM} \wedge \vec{dF} = \int_0^L \begin{pmatrix} r \\ 0 \\ 0 \end{pmatrix}_{12} \wedge \begin{pmatrix} 0 \\ -1/2 \rho l \omega^2 r^2 C_y dr \\ 1/2 \rho l \omega^2 r^2 C_z dr \end{pmatrix}_{12}$$

$$\vec{M_F(O)} = \int_0^L \begin{pmatrix} 0 \\ -1/2 \rho l \omega^2 r^3 C_z dr \\ -1/2 \rho l \omega^2 r^3 C_4 dr \end{pmatrix} = \begin{bmatrix} 0 \\ r^4/4 \\ r^4/4 \end{bmatrix}_0^L \begin{matrix} \times \left(-\frac{1}{2} \rho l \omega^2 L_t\right) \vec{y_2} \\ \times \left(-\frac{1}{2} \rho l \omega^2 C_4\right) \vec{z_{1,2}} \end{matrix}$$

$$\vec{M_F(O)} = \begin{pmatrix} 0 \\ -1/8 \, \rho l \omega^2 \times L^4 C_z \\ -1/8 \, \rho l \omega^2 \times L^4 C_4 \end{pmatrix}_{12}$$

hence we found the sum and moment at O.

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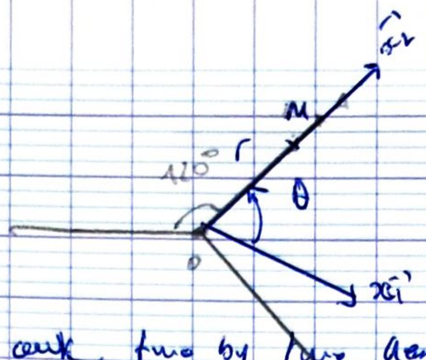
1.2) a)



$d\vec{T}$ cancel each, two by two hence we need only one blade to consider

$\vec{S} = \int 12 d\vec{T} + \int 3 d\vec{P}$

$= -\frac{1}{2}\cancel{\rho l \omega}^2 C_4 \frac{L^3}{3} \vec{y_2} + \frac{3}{2}\rho l \omega^2 C_2 \frac{L^3}{3} \vec{z_{1/2}}$

b) The moment generated by $d\vec{P}$ at O is null (C_x)

$M_P(\vec{O}) = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$ we need to find the one generated by the three blades by $d\vec{T}$ the drag force.

$M_T(\vec{O}) = 3\vec{OM} \wedge d\vec{T} = \begin{pmatrix} 0 \\ 0 \\ -3/8\, \rho l \omega^2 L^4 C_4 \end{pmatrix}_{/2}$

$\left\{ \omega_{\text{blades}} \right\}_O = \left\{ \begin{matrix} 0 \\ -1/2 \cancel{\rho l}\omega^2 C_4 \frac{L^3}{3} \\ 3/2 \rho l \omega^2 C_2 \frac{L^3}{3} \end{matrix} \middle| \begin{matrix} 0 \\ 0 \\ -\frac{3}{8}\rho l \omega^2 L^4 C_4 \end{matrix} \right\}$

1.3) weight $\vec{P} = -mg\vec{z_1}$

equilibrium for the helicopter.

$\sum \vec{F}_{ext/heli} = \vec{0} \Rightarrow \begin{cases} R_x + T_1 = 0 \\ R_y + Q + T_2 = 0 \\ R_z + P_c - mg = 0 \end{cases} \Rightarrow \begin{matrix} R_x = -T_1 \\ R_y = -T_2 - Q \\ R_z = mg - P_c \end{matrix}$

$\sum \vec{M_{ext/hx}(O)} = \vec{0} \Leftrightarrow \vec{M_{A1/MR}(O)} + \vec{M_{A1/TR}(O)} + \vec{M_{A1/c_0}(O)} + \vec{M_P(O)} = \vec{0}$

(*) (**) (***)

$M_r \cdot \vec{z_1}$

$\vec{CA} + \vec{AB}$

$\vec{OB} = \begin{pmatrix} -b \\ -d \\ -a \end{pmatrix}$ (*) $\vec{M_{A1/TR}(O)} = \vec{M_{A1/TR}(B)} + \vec{OB} \wedge \vec{R_{A1/TR}} = M_Q \cdot \vec{y_1} + \begin{pmatrix} -b \\ -d \\ -a \end{pmatrix} \wedge \begin{pmatrix} 0 \\ Q \\ 0 \end{pmatrix} = \begin{pmatrix} a \cdot Q \\ 0 \\ -b \cdot Q \end{pmatrix}$

$\vec{M_{A1/TR}(O)} = \begin{pmatrix} a \cdot Q \\ M_Q \\ -b Q \end{pmatrix}_{/1}$

(**) $\vec{M_{A1/c_0}(O)} = \underset{0}{\vec{M_{A1/c_0}(A)}} + \vec{OA} \wedge \vec{R_{A1/c_0}} = \begin{pmatrix} 0 \\ 0 \\ -a \end{pmatrix} \wedge \begin{pmatrix} T_1 \\ T_2 \\ P_c \end{pmatrix} = \begin{pmatrix} a\, T_2 \\ -a\, T_1 \\ 0 \end{pmatrix}_{/1}$

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$$\vec{OG} = \vec{OA} + \vec{AG} = \begin{pmatrix} x_G \\ 0 \\ -a \end{pmatrix}$$

(wrt) $\vec{M_P(O)} = \vec{OG} \wedge \vec{P} = \begin{pmatrix} x_G \\ 0 \\ -a \end{pmatrix} \wedge \begin{pmatrix} 0 \\ 0 \\ -mg \end{pmatrix} = \begin{pmatrix} 0 \\ x_G mg \\ 0 \end{pmatrix}_{B_1}$

hence: $\sum \overrightarrow{M_{ext/heli}}(O) = \vec{0}$

$$\Leftrightarrow \begin{cases} a \cdot Q + a\, T_2 = 0 \Leftrightarrow Q = T_2 \\ M_Q + x_G mg - a\, T_1 = 0 \Leftrightarrow M_Q = a\, T_1 - x_G mg \\ M_R - b \cdot Q = 0 \Leftrightarrow M_R = bQ \Leftrightarrow Q = \frac{M_R}{b} \end{cases}$$

hence the tail rotor, allow the helicopter not to spin continuously arow the axis of the main rotor, It allows the translation and the chopper can fly without spinning.

1.4) Associated to the wrench used in 1.2)

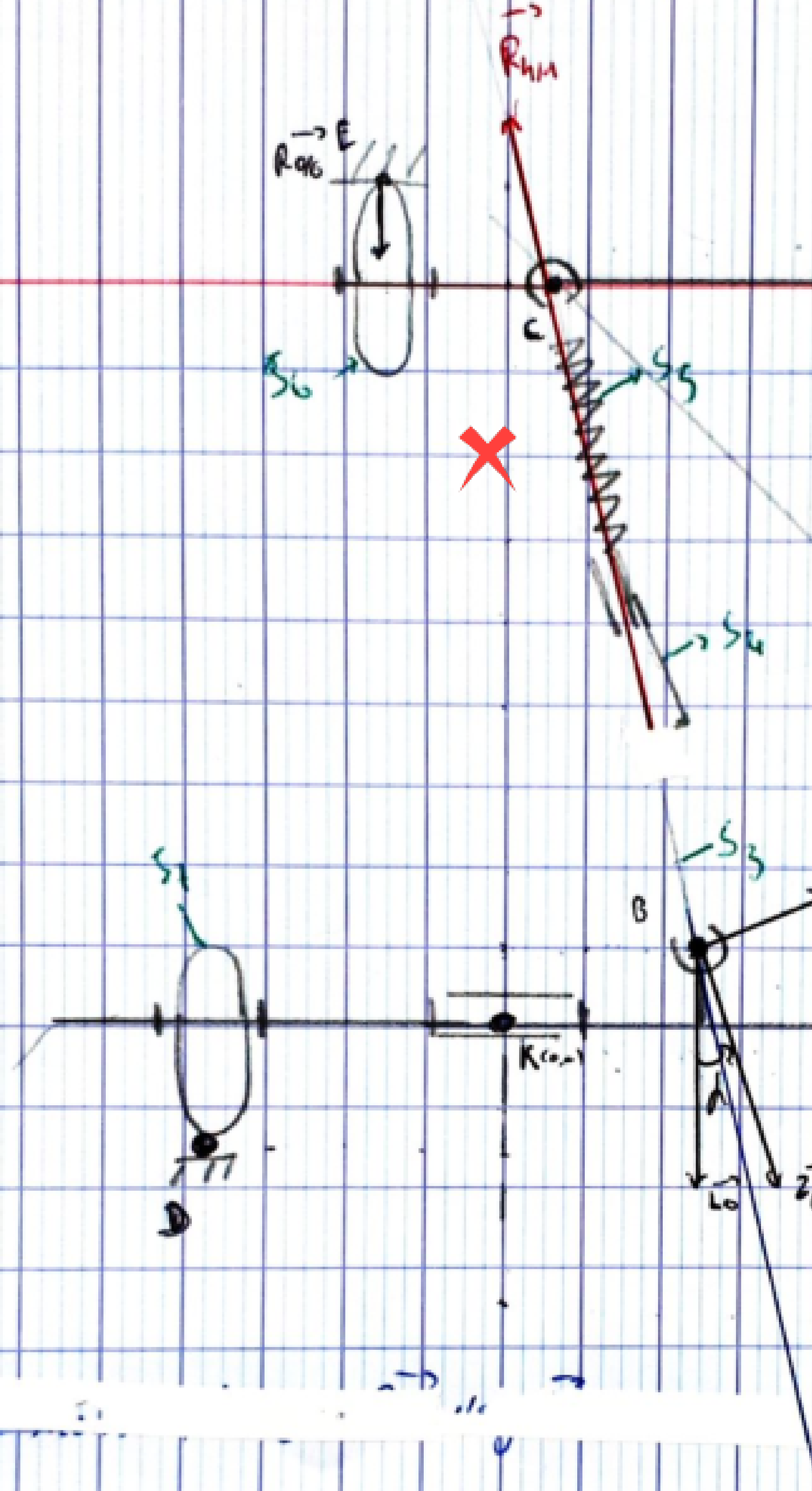
we will have a translation along x_1 since $\{ \omega_{main\ blades} \}_G = \left\{ \begin{matrix} 0 \\ 0 \\ -\frac{3}{8} \rho \ell \omega^2 L^4 \end{matrix} \right\}$

and rois along $\vec{u_1}$.

$2083\ N \cdot cm^{-1}$

$\vec{R_{41}}$: 6cm

$\vec{R_{12}}$ 3.8cm.



$\vec{R_{6/1}}$: $\vec{R_{6/1}}$ and $\|\vec{R_{2/1}}\| = 12488$ N.

$\sum \vec{R_{ext/6}} = \vec{0} \Leftrightarrow \vec{R_{rail/6}} + \vec{R_{1/6}} = \vec{0}$

hence: $\vec{R_{1/6}} = -\vec{R_{rail/6}}$

$\downarrow \vec{R_{6/1}}$ $\uparrow \vec{R_{rail/6}}$

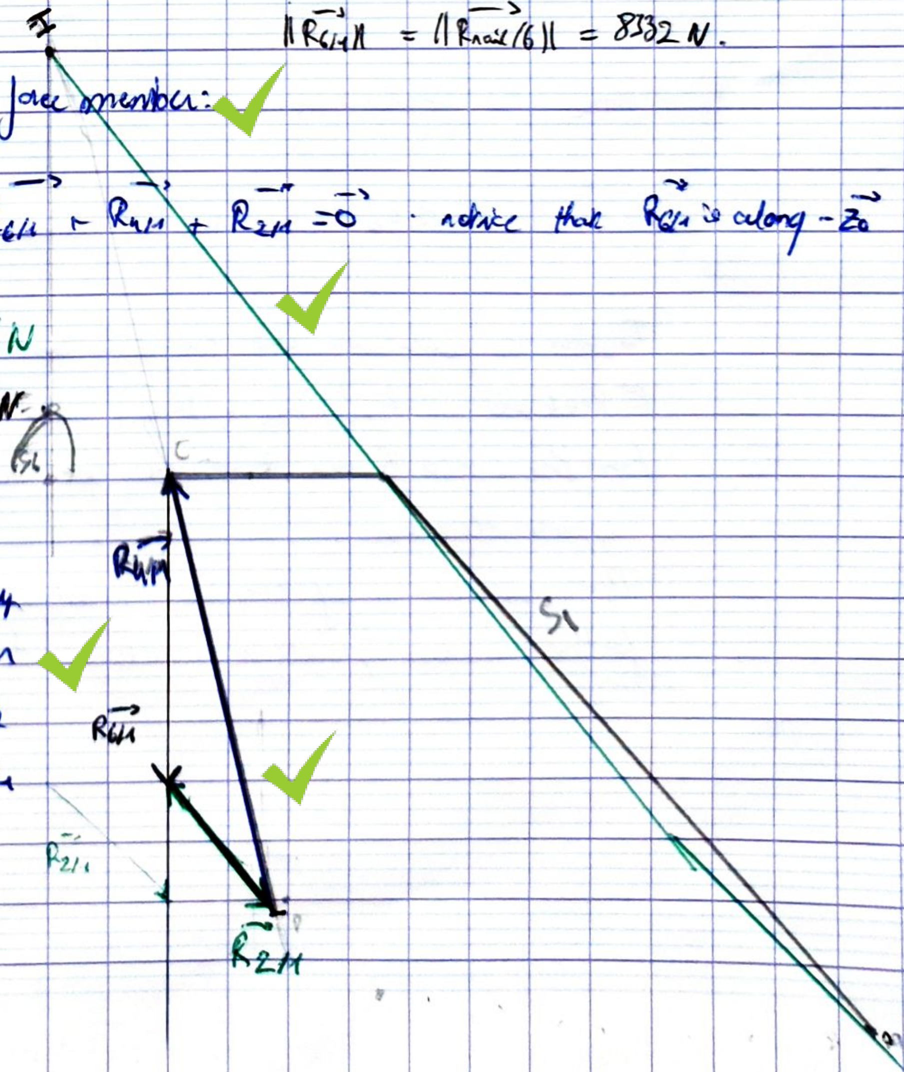
$\|\vec{R_{6/1}}\| = \|\vec{R_{rail/6}}\| = 8332$ N.

Solid 1 is a three force member:

$\sum \vec{R_{ext/1}} = \vec{0} \Leftrightarrow \vec{R_{6/1}} + \vec{R_{4/1}} + \vec{R_{2/1}} = \vec{0}$. notice that $\vec{R_{6/1}}$ is along $-\vec{z_0}$

hence $\|\vec{R_{2/1}}\| = 4166$ N

$\|\vec{R_{4/1}}\| = 8332$ N

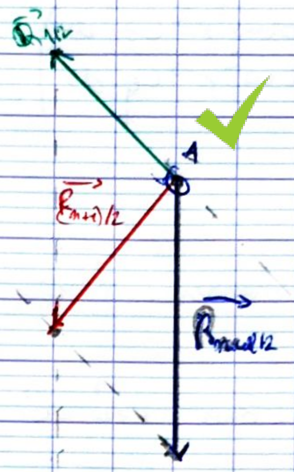


Using I the crossing point we build our triangle and find the equilibrium for S_1 and S_6

2.2) Equilibrium of the assembly {2, 7, 8}

A) $\vec{R}_{(\text{manivelle})/2} + \vec{R}_{1/2} = -\vec{R}_{2/1} + \vec{R}_{\text{nacelle}/2} =$

$\|\vec{R}_{m+1/2}\| = 5207{,}5N$.



B) $\vec{R}_{m+1,3/2}$ combining solid 5, 4, 3 leads to a 2 force member.

$\Sigma \vec{R}_{ext/3} = \vec{0} \Leftrightarrow \vec{R}_{2/3} + \vec{R}_{1/4} = \vec{0} \Rightarrow \vec{R}_{2/3} = \vec{R}_{4/1}$

$\Leftrightarrow \vec{R}_{3/2} = -\vec{R}_{4/1}$.

hence by construction we can find on page 4)

$\|\vec{R}_{m+1+3/2}\| = 15622{,}5N$ close to 30° direction.

To solve its equilibrium we need to sum up the forces computed
$\Sigma \vec{R}_{ext/2} = \vec{0} \Rightarrow \vec{R}_{7/2} + \vec{R}_{8/2} + \vec{R}_{m+1+3/2} = \vec{0}$ and build our triangle
For the solid 8 and 7 it will be like for the one in solid 6.
: opposite direction..
The orientation of $\vec{R}_{m+1+3/2}$ is interesting as it allows some safety for the users parallel or close to the weighting forces.