

Notes: - ① ② they generate a moment  $(a, b, \theta) \Rightarrow (\frac{1}{2} a_1 a_2 a_3, b, \theta)$   
 $\begin{pmatrix} i \\ j \\ k \end{pmatrix} \begin{pmatrix} i \\ j \\ k \end{pmatrix}$

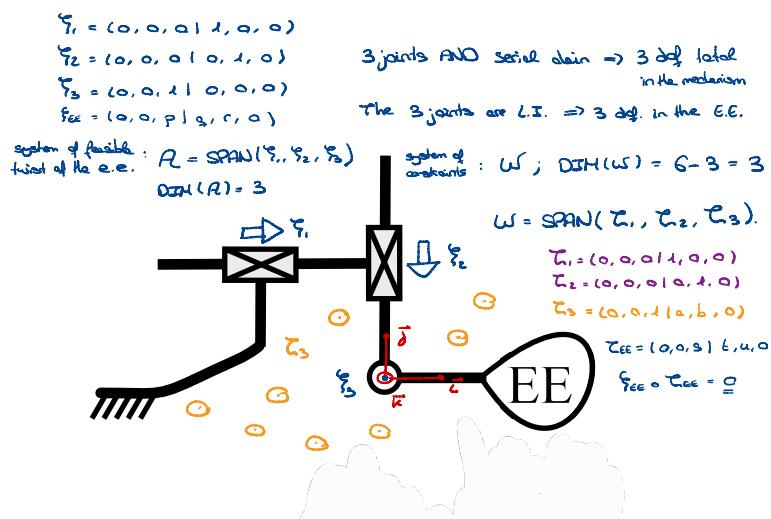
- Moment 1 to  $F_x$  direction doesn't matter

Name: \_\_\_\_\_  
 Student number: \_\_\_\_\_

DH

1. For each mechanism in the figures following: Ines Hawala

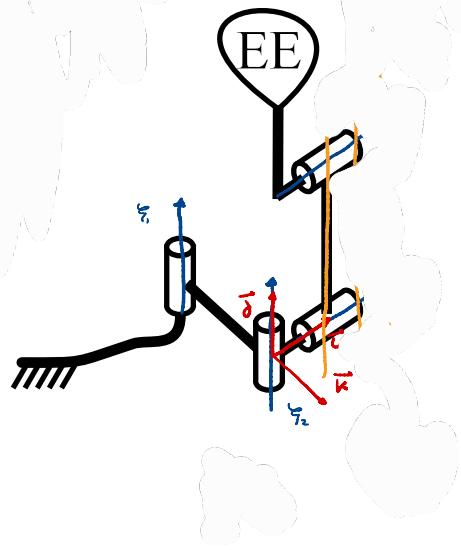
- ? - show the geometry parameters
- ✓ - draw the twists of the joints and note down their coordinates in a reference frame of your choice
- ✓ - write the degree of freedom of the mechanism and of the EE writing a proof of the answers
- ✓ - write a base of the system of feasible twists of the EE
- ✓ - write the dimension of the structural constraint applied by the mechanism between ground and EE
- ✓ - give a base of the wrench system of constraints and explain forces and moments in that system



$\xi_1 = (0, 0, a, 1, a, b, 0)$   
 $\xi_2 = (0, 0, 0, 1, 0, 0, 0)$   
 $\xi_3 = (0, 0, 1, 1, a, 0, 0)$   
 $\xi_{EE} = (0, 0, p_1 g, r, 0)$

3 joints AND serial chain  $\Rightarrow$  3 dof total in the mechanism  
 The 3 joints are L.I.  $\Rightarrow$  3 dof in the E.E.

system of feasible twist of the E.E. :  $R = \text{SPAN}(\xi_1, \xi_2, \xi_3)$ ;  $\text{dim}(R) = 3$



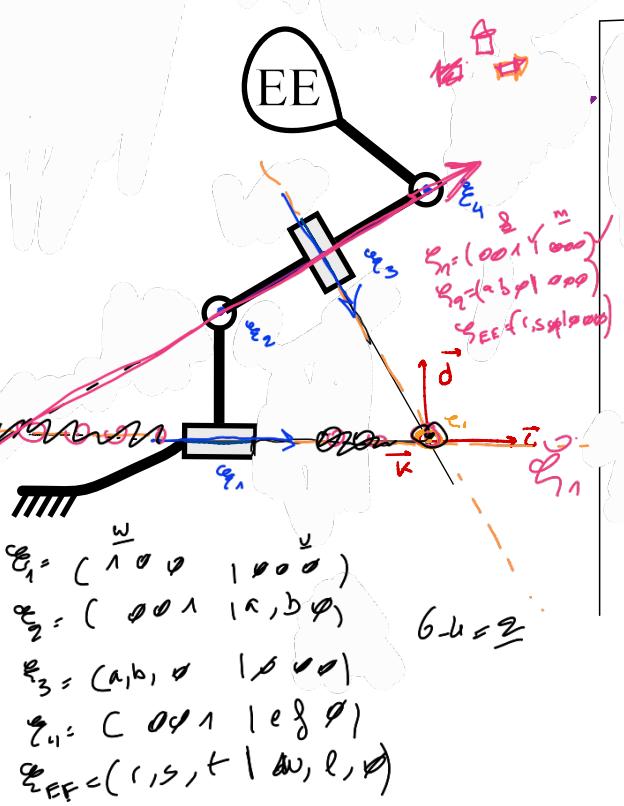
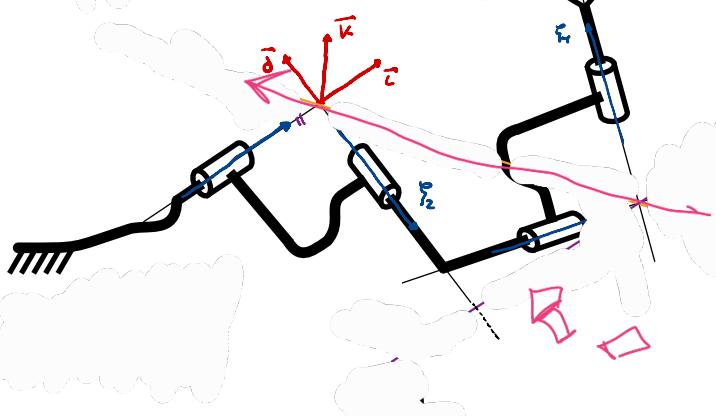
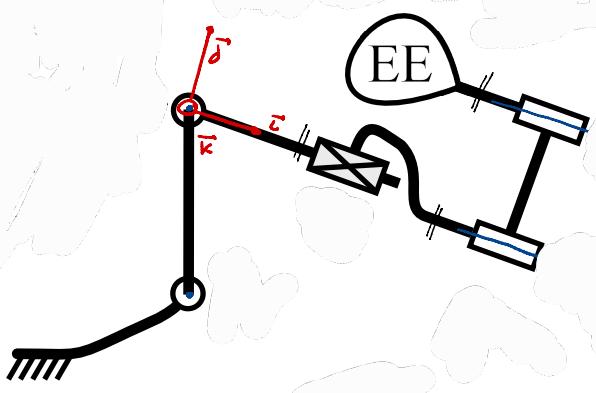
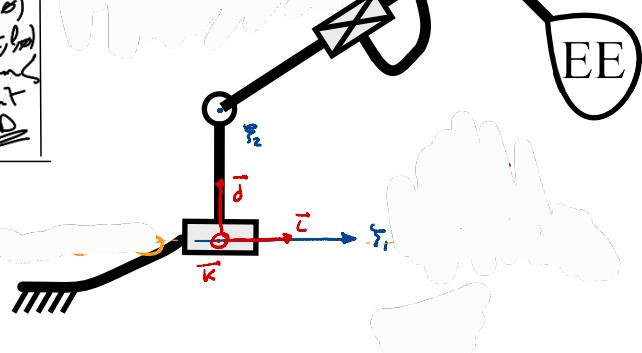
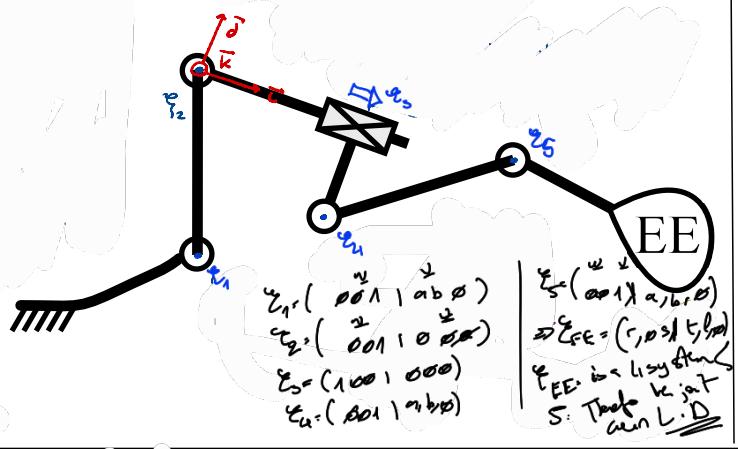
(2)

$\xi_1 = (0011a, 0)$   
 $\xi_2 = (0011, 000)$   
 $\xi_3 = (100, 10, 00)$   
 $\xi_4 = (0, 0, 1, 1, 0, 0)$

$\xi_{EE} = (0, 0, 0, 0, 0, 0)$

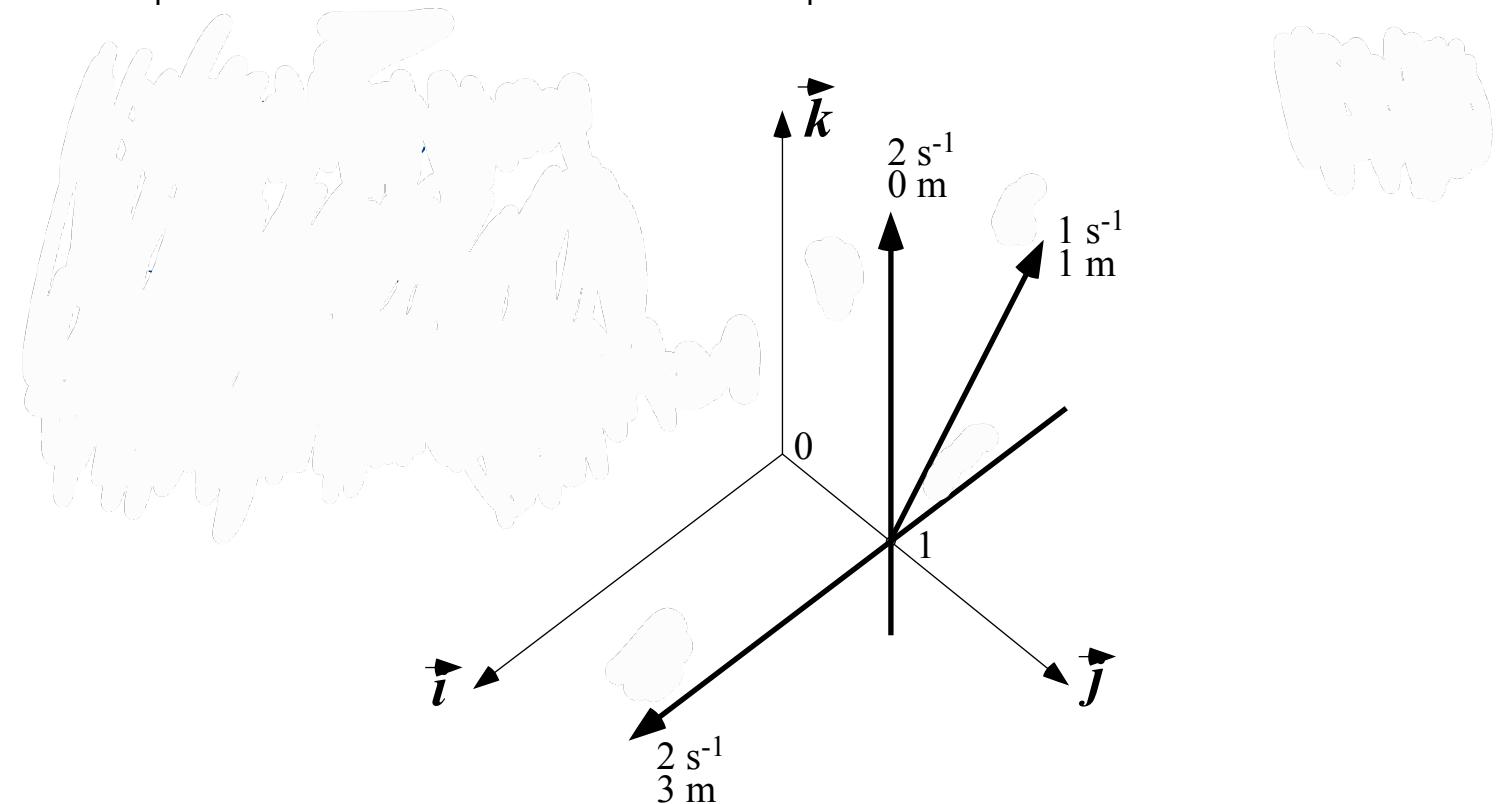
$\zeta_1 = (0000, 10, 00)$   
 $\zeta_2 = (0000, 0, 0, 0)$   
 $\zeta_3 = (00, 1, 0, 1, b, 0)$   
 $\zeta_4 = (0, 1, 0, 1, 0, 0)$   
 $\zeta_{EE} = (0, 0, 0, 1, 0, 0)$

usys

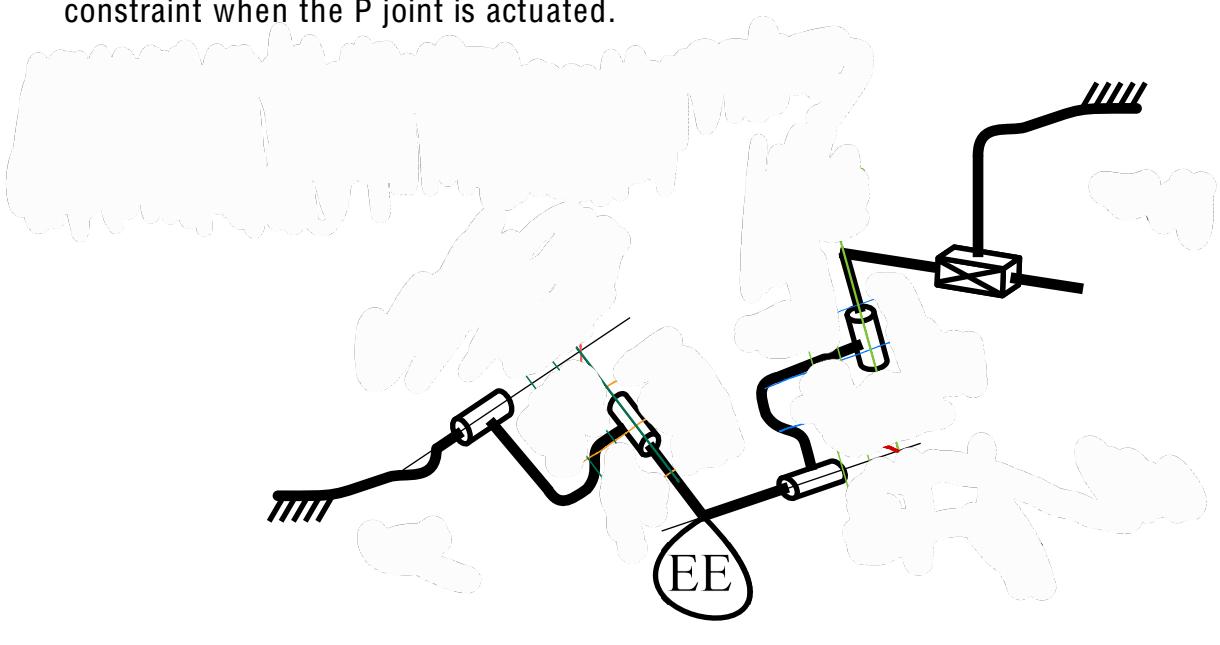


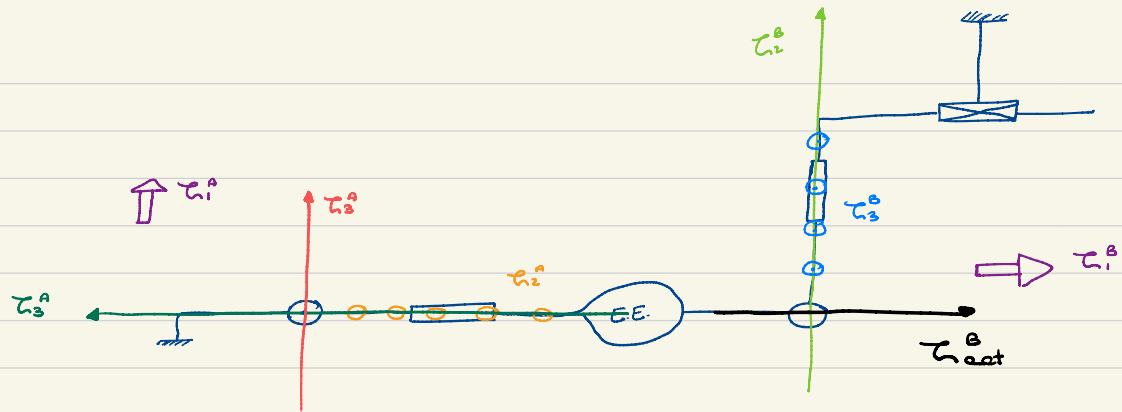
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2. Write the coordinates of the three twists shown in picture that follows in the reference frame given. The lines of the three twists are through the point (0,1,0); speed and pitch are noted in the picture. Draw the rotation and translation components of each twist.



3. For the following mechanism draw the structural constraint applied to the EE and the actuated constraint when the P joint is actuated.





$$w^a = \text{SPAN}(\tau_1^a, \tau_2^a, \tau_3^a, \tau_4^a)$$

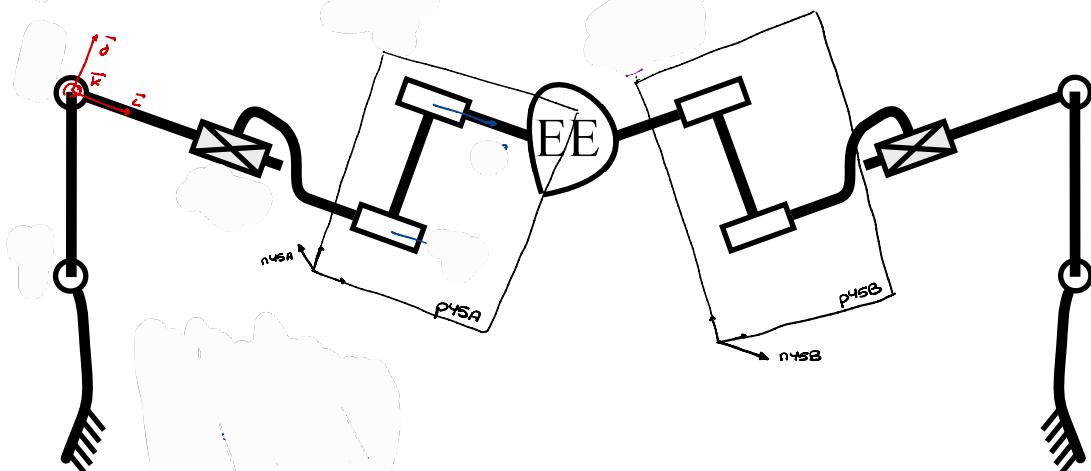
$$w^b = \text{SPAN}(\tau_1^b, \tau_2^b, \tau_3^b).$$

$$w = w^a + w^b ; \text{DIM}(w) = \text{DIM}(w^a) + \text{DIM}(w^b) - \text{DIM}(w^a \cap w^b) = 4 + 3 - ?$$

$$U^a = w^a$$

$$U^b = w^b + \text{SPAN}(\tau_4^b)$$

4. A mechanism has two legs with same architecture and geometry as in the picture following. Call  $p_{45A}$  the plane of the joints 4 and 5 of the left leg and  $n_{45A}$  its normal direction;  $p_{45B}$  the same plane for the right leg and  $n_{45B}$  its normal direction. Draw on the picture and explain with few words the combined structural constraint on the EE when  $n_{45A}=n_{45B}$ .



5. Write by coordinates the geometric jacobian of the mechanisms below in a reference frame of your choice.

