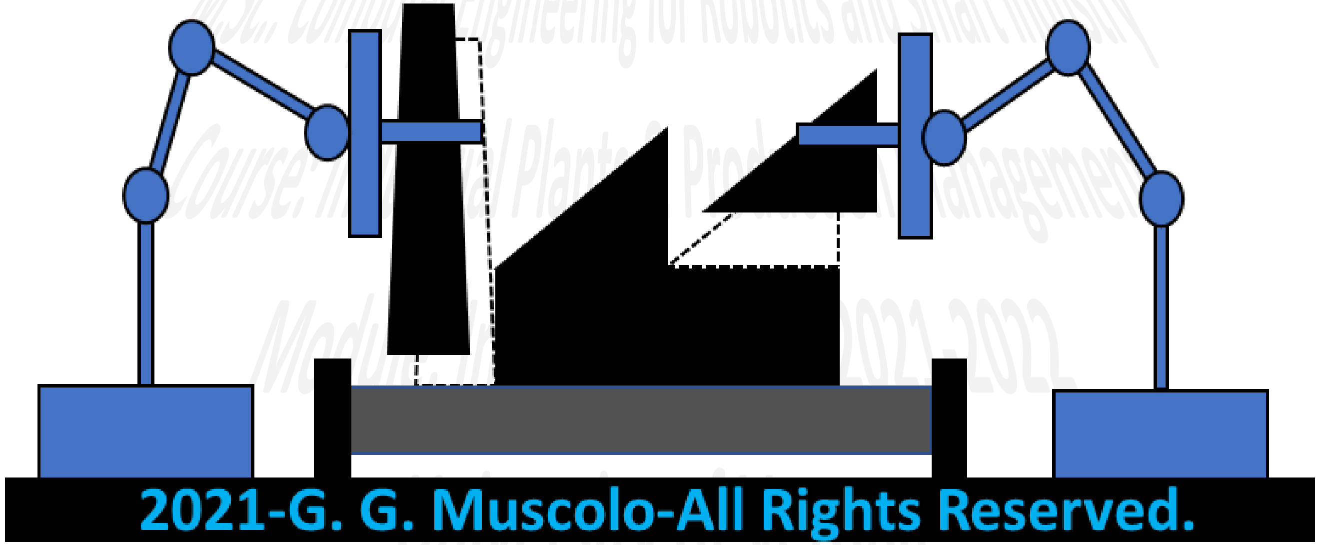

Industrial Plants

(S.S.D. ING-IND/13)

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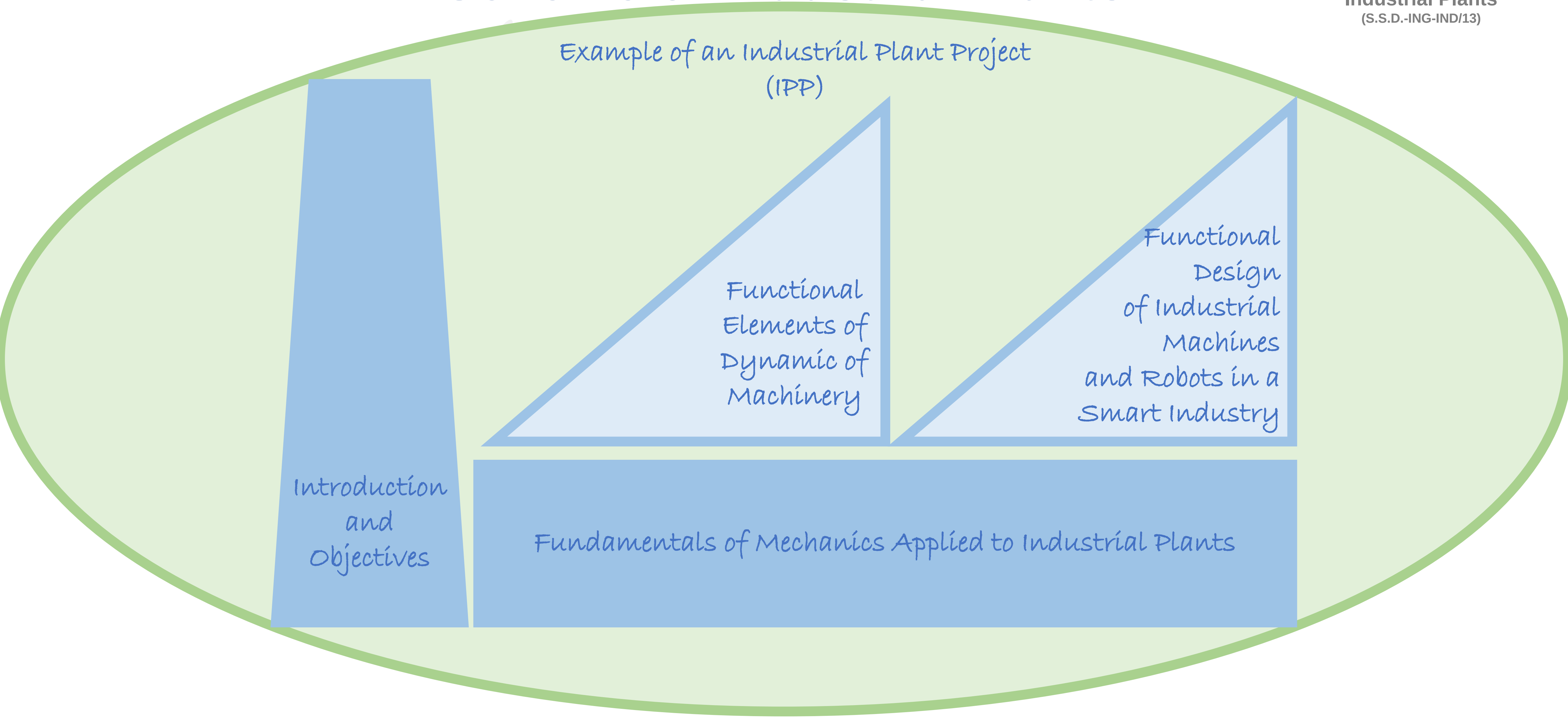
Program

1. **Introduction and Objectives**
2. **Fundamentals of Mechanics Applied to Industrial Plants**
3. **Functional Design of Industrial Machines and Robots in a Smart Industry**
4. Functional Elements of Dynamic of Machinery
5. Example of an Industrial Plant Project (IPP)

Scheme of Industrial Plants



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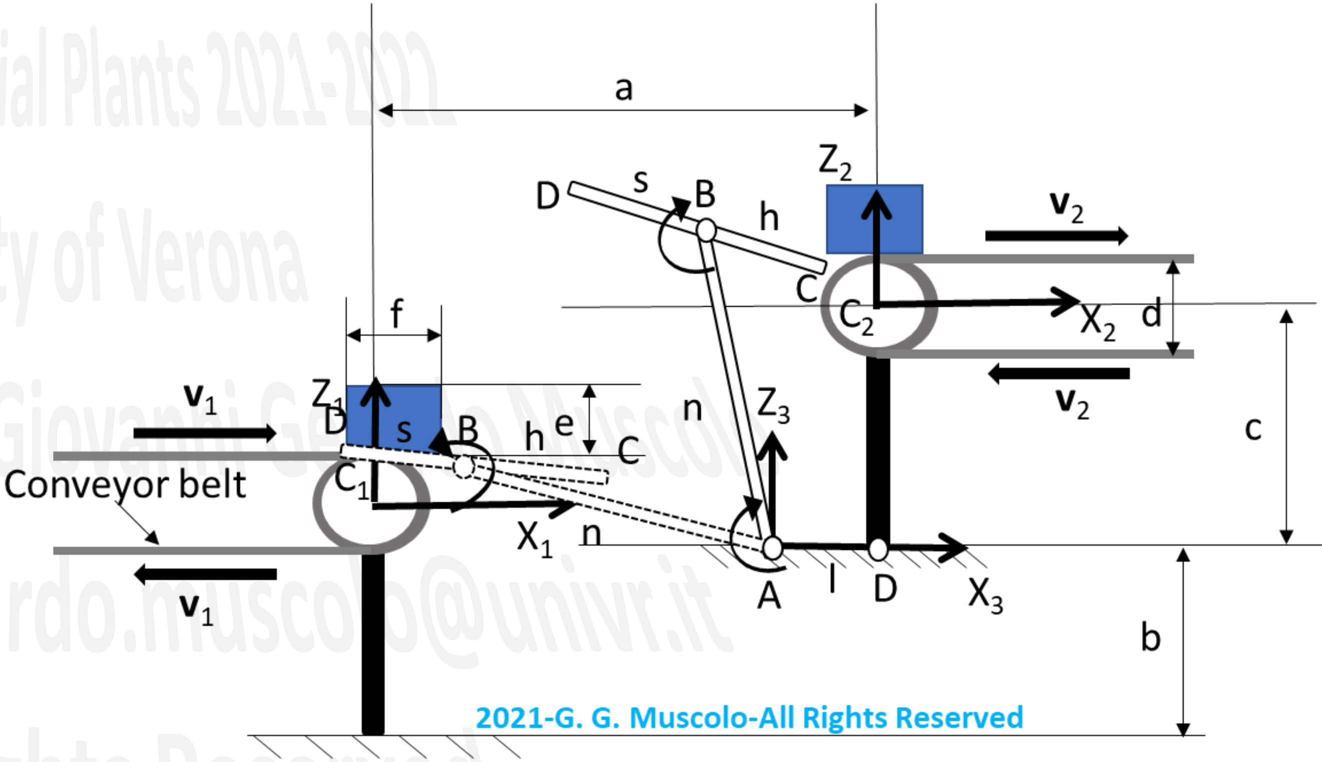
Exercise (Functional Design):

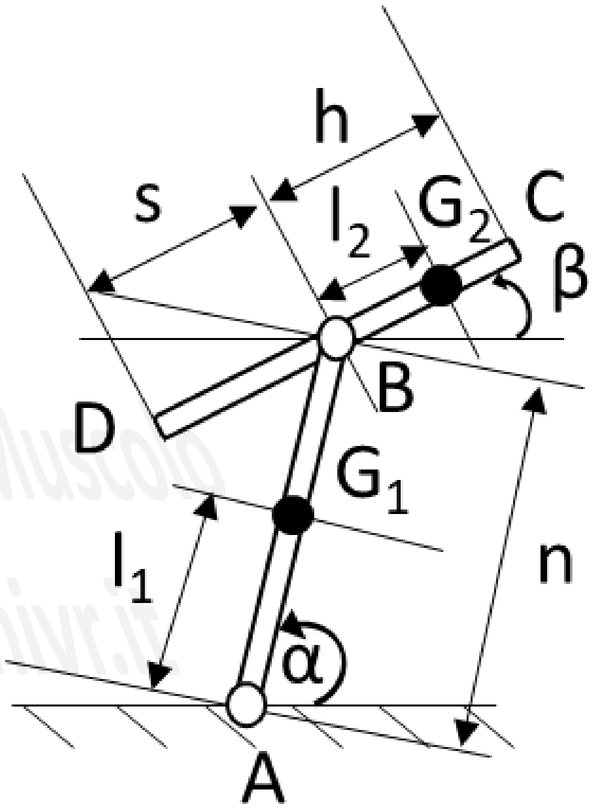
In this exercise we will study the behavior of the mechanical system with 2 DoFs, modifying the technical specification.



Exercise (Functional Design):

We can start to define the general procedure for a simple mechanism with 2 bars as shown in figure.

We will try to find positions, velocities, accelerations, reaction forces, in order to understand the general behavior of the mechanism.



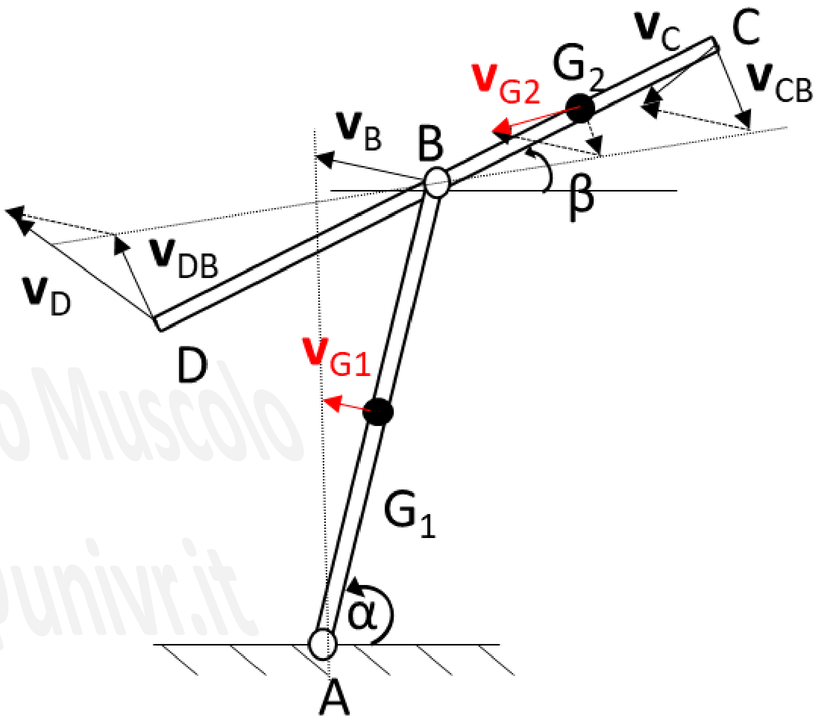
Exercise (Functional Design):

In figure, we can see the velocities.

In particular, $\mathbf{v}_B$ will be orthogonal to $\overline{AB}$, like $\mathbf{v}_{G1}$.

$\mathbf{v}_{CB}$ will be orthogonal to $\overline{BC}$, like $\mathbf{v}_{G2B}$.

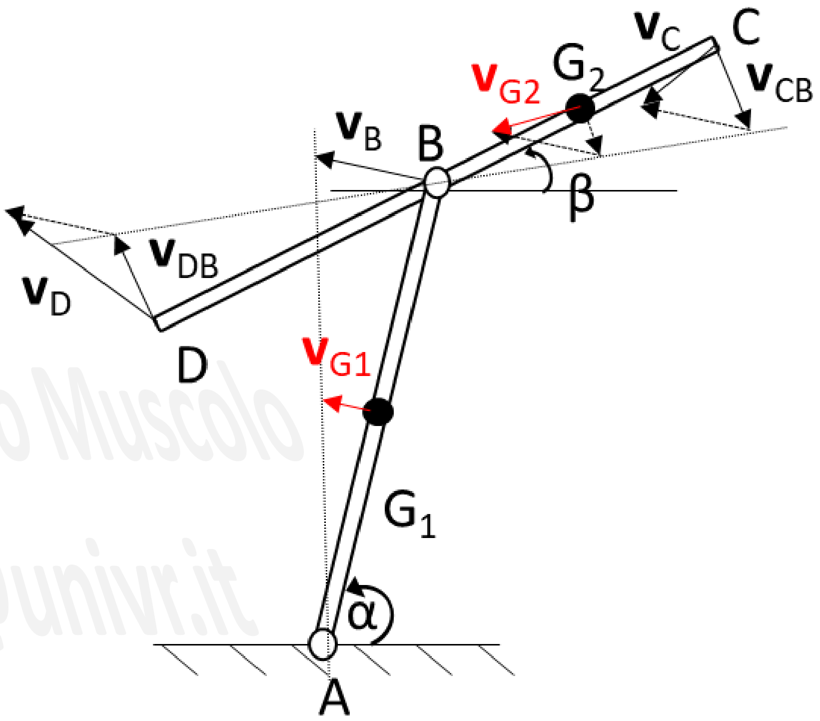
$\mathbf{v}_C$ is obtained by the sum of $\mathbf{v}_B$ and $\mathbf{v}_{CB}$ like how we calculated in the part of fundamental of Mechanics applied to industrial plants.



Exercise (Functional Design):

46) $\boldsymbol{v}_B = \boldsymbol{v}_{dB} + \boldsymbol{v}_{relB} = \boldsymbol{v}_A + \boldsymbol{v}_{BA} = \boldsymbol{v}_A + \dot{\alpha}\boldsymbol{k} \times \boldsymbol{AB};$

47) $\boldsymbol{v}_C = \boldsymbol{v}_{dC} + \boldsymbol{v}_{relC} = \boldsymbol{v}_B + \boldsymbol{v}_{CB} = \boldsymbol{v}_B + \dot{\beta}\boldsymbol{k} \times \boldsymbol{BC};$



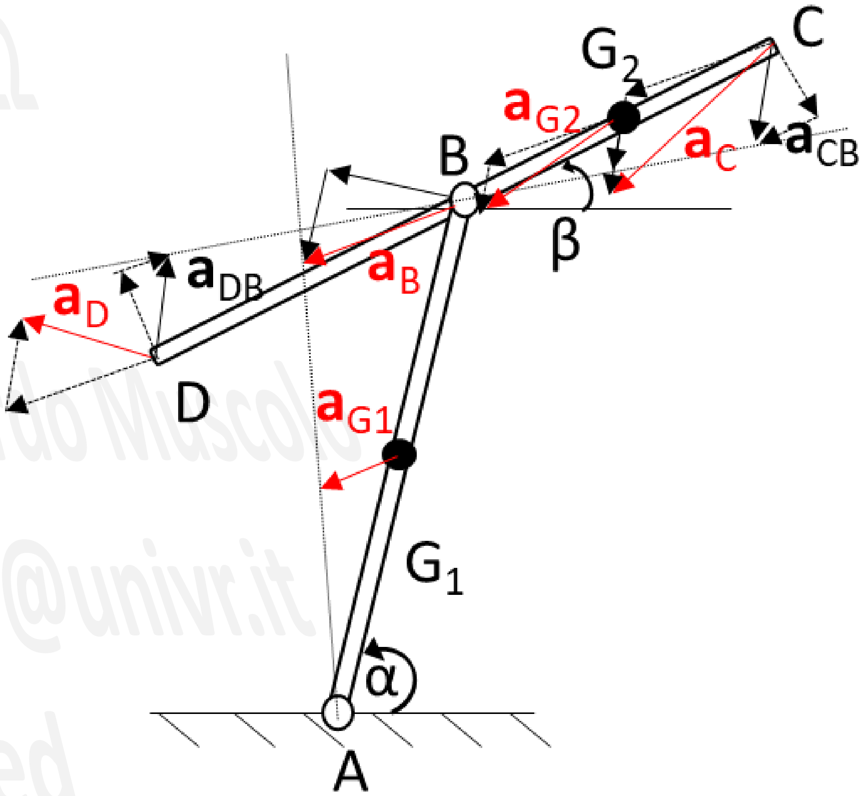
Exercise (Functional Design):

In figure, we can see the accelerations.

In particular, $\mathbf{a}_B$ will be obtained by the sum of components orthogonal and parallel to $\overline{AB}$, like $\mathbf{a}_{G1}$.

$\mathbf{a}_{CB}$ will be also obtained by the sum of components orthogonal and parallel to $\overline{BC}$, like $\mathbf{a}_{G2B}$.

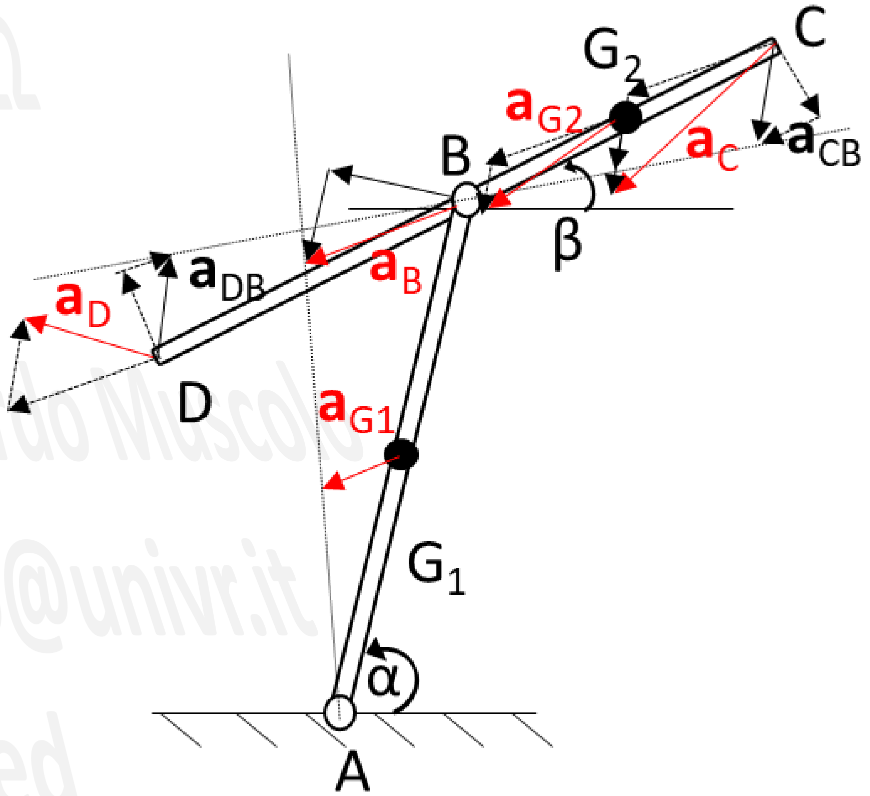
$\mathbf{a}_C$ is obtained by the sum of $\mathbf{a}_B$ and $\mathbf{a}_{CB}$ like we calculated in the part of fundamental of Mechanics applied to industrial plants.

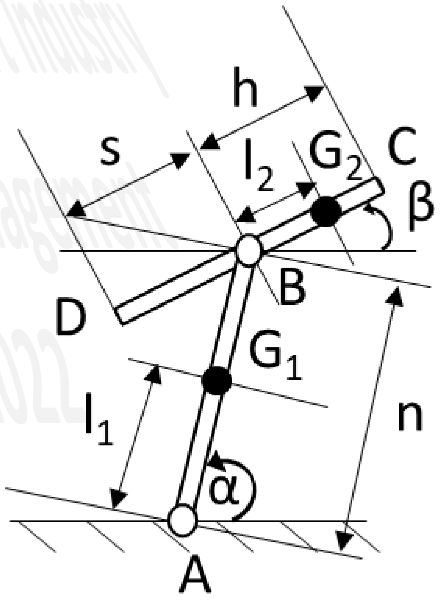


Exercise (Functional Design):

48) $\underline{\boldsymbol{a}_B} = \boldsymbol{a}_{relB} + \boldsymbol{a}_{dB} + \boldsymbol{a}_{cB} = \boldsymbol{a}_A + \ddot{\alpha}\boldsymbol{k} \times \overline{\boldsymbol{AB}} - \dot{\alpha}^2\overline{\boldsymbol{AB}};$

49) $\underline{\boldsymbol{a}_C} = \boldsymbol{a}_{relC} + \boldsymbol{a}_{dC} + \boldsymbol{a}_{cC} = \boldsymbol{a}_B + \ddot{\beta}\boldsymbol{k} \times \overline{\boldsymbol{BC}} - \dot{\beta}^2\overline{\boldsymbol{BC}};$





Exercise (Functional Design):

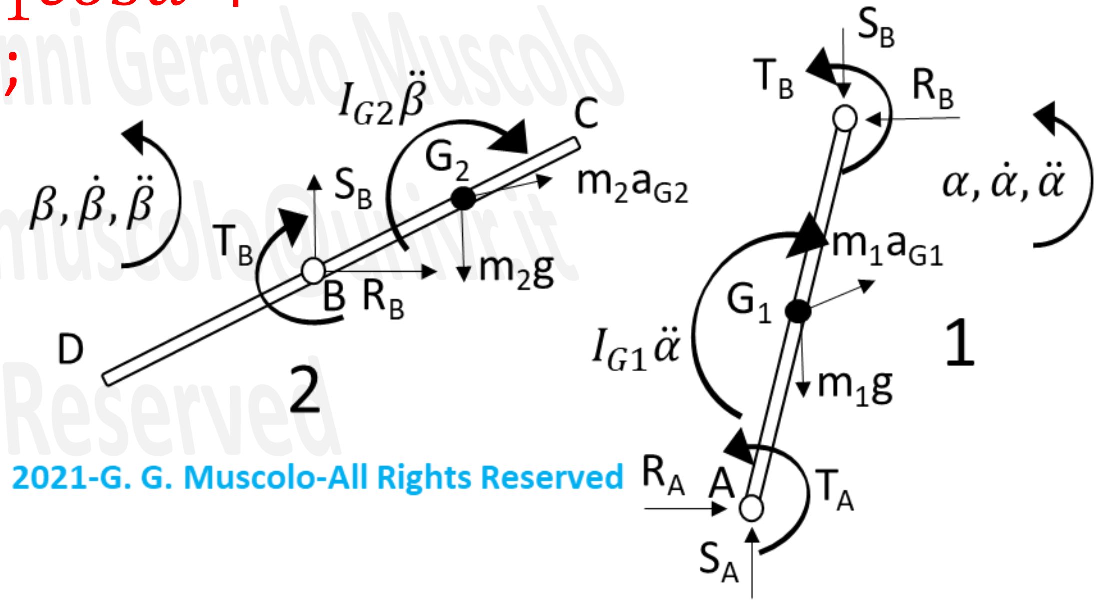
Link 1:

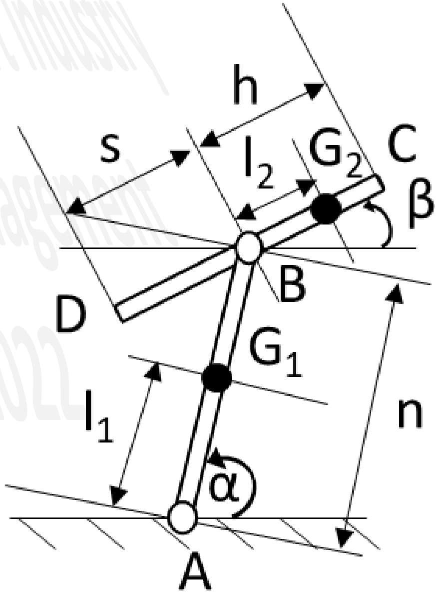
50) $I_1 = I_{G1} + m_1 l_1^2;$

51) $-I_{G1}\ddot{\alpha} + T_A + T_B + R_A l_1 sin\alpha - S_A l_1 cos\alpha + R_B(n - l_1)sin\alpha - S_B(n - l_1)cos\alpha = 0;$

52) $m_1\ddot{x}_{G1} - R_B + R_A = 0;$

53) $m_1\ddot{z}_{G1} - m_1 g + S_A - S_B = 0;$





Exercise (Functional Design):

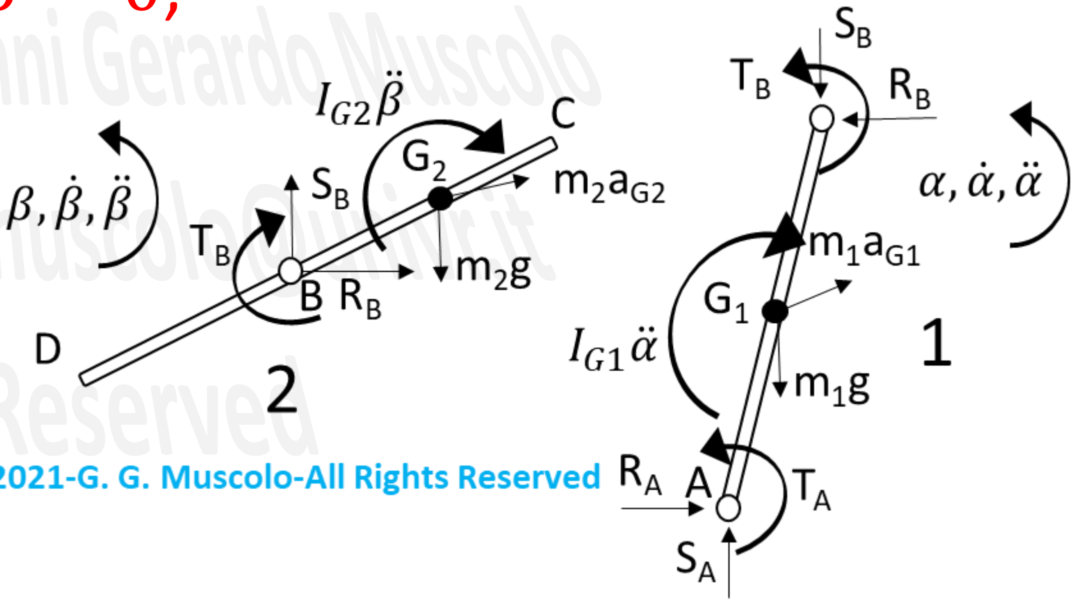
Link 2:

54) $I_2 = I_{G2} + m_2 l_2^2;$

55) $-I_{G2}\ddot{\beta} - T_B + R_B l_2 sin\beta - S_B l_2 cos\beta = 0;$

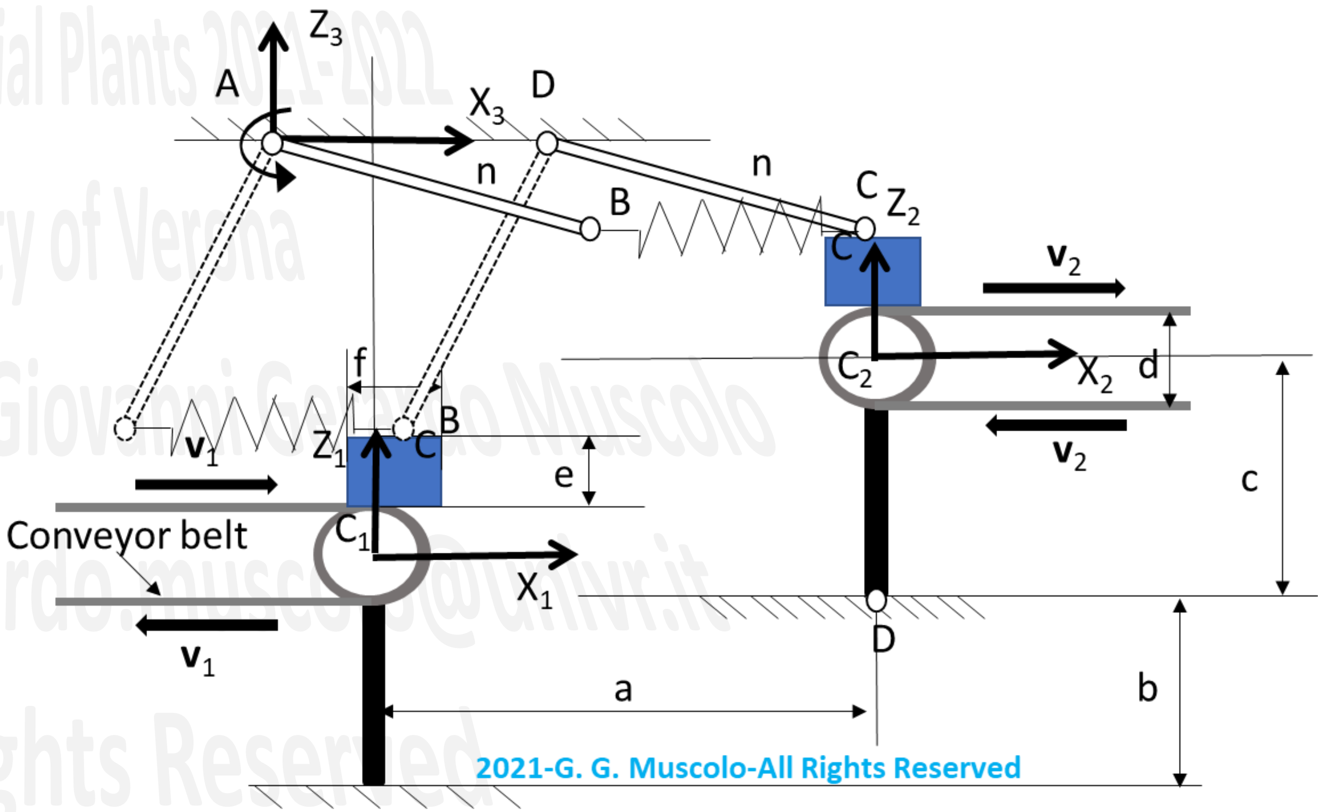
56) $m_2 \ddot{x}_{G2} + R_B = 0;$

57) $m_2 \ddot{z}_{G2} - m_2 g + S_B = 0;$



Exercise (Functional Design):

In this exercise we will study the general behavior of the novel mechanical system shown in figure.

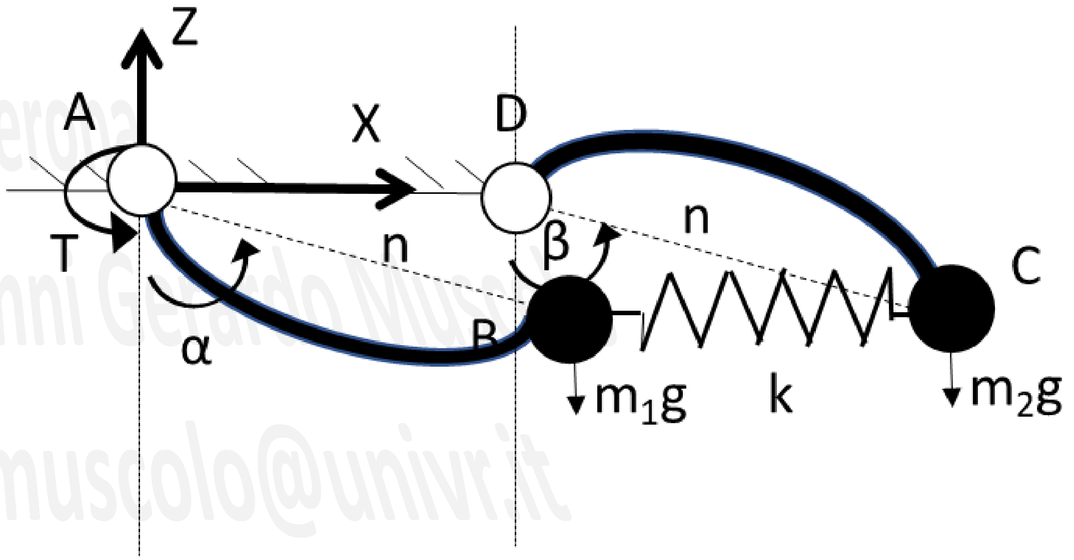


Exercise (Functional Design):

The system will be solved using two approaches:

-) Newtonian approach;

-) Lagrangian approach;



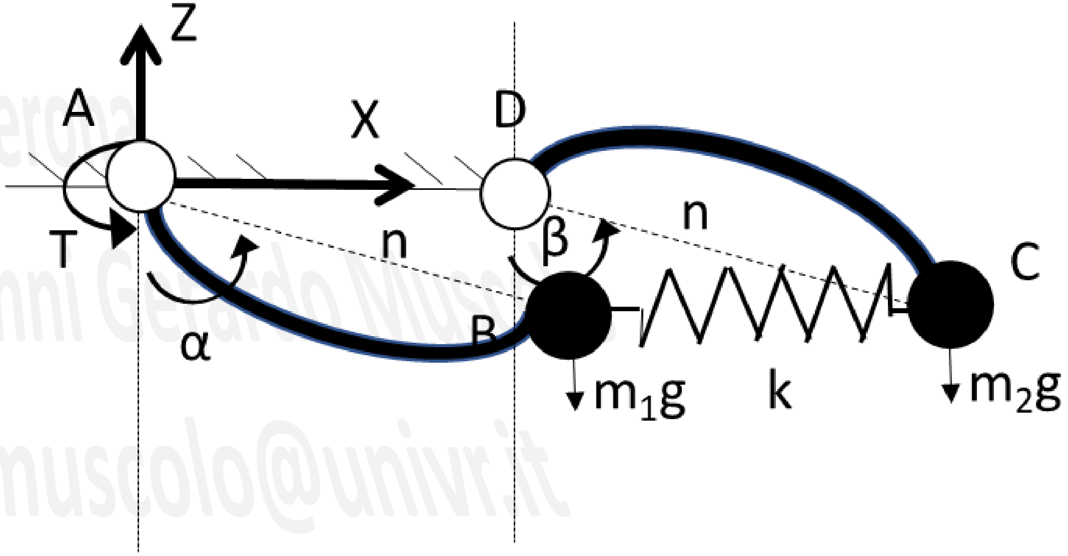
Exercise (Functional Design):

-) Newtonian approach:

The equations have the same form of above.

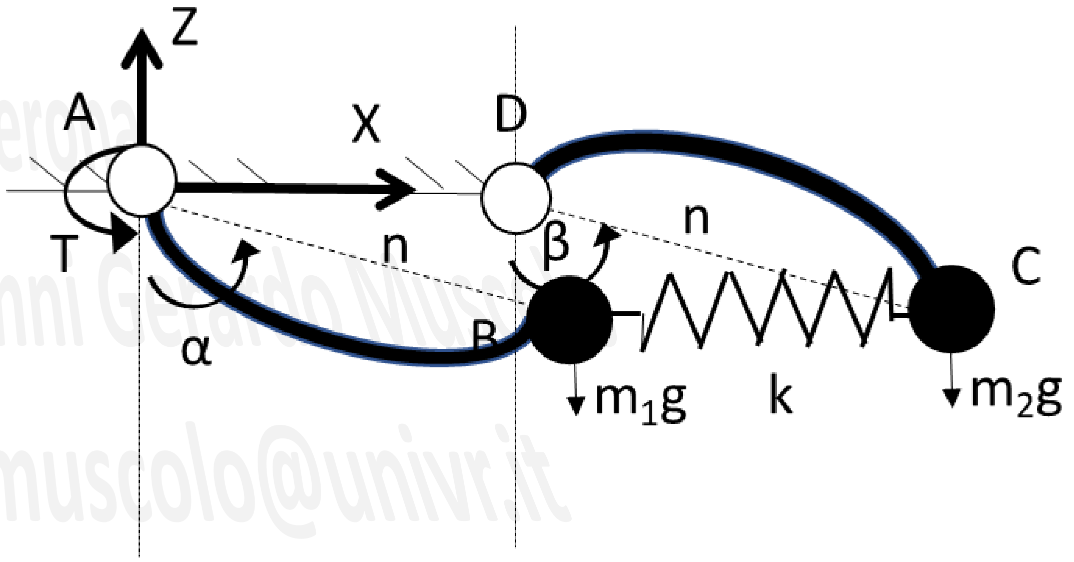
58) $m_1 n^2 \ddot{\alpha} + kn^2 cos\alpha(sin\alpha - sin\beta) + m_1 gnsin\alpha = T;$

59) $m_2 n^2 \ddot{\beta} + kn^2 cos\beta(sin\beta - sin\alpha) + m_2 gnsin\beta = 0;$



Exercise (Functional Design):

-) Newtonian approach:



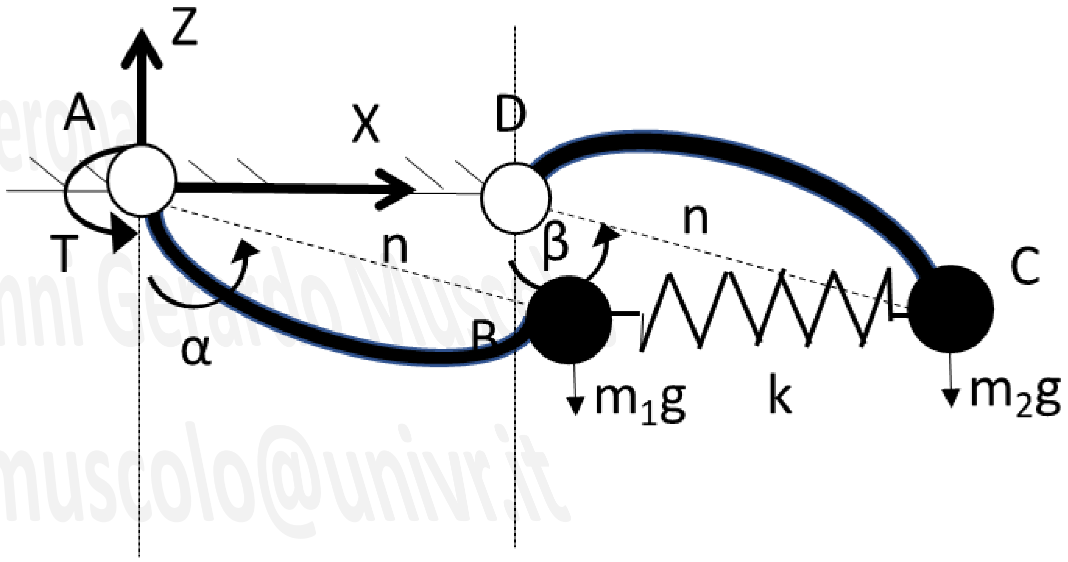
With approximation

58) $m_1 n^2 \ddot{\alpha} + k n^2(\alpha - \beta) + m_1 g n \alpha = T;$

59) $m_2 n^2 \ddot{\beta} + k n^2(\beta - \alpha) + m_2 g n \beta = 0;$

Exercise (Functional Design):

-) Lagrangian approach:



In this case we must use the Lagrange's equation:

60) $\frac{d}{dt}\left(\frac{\partial E}{\partial \dot{q}}\right) - \frac{\partial E}{\partial q} + \frac{\partial U}{\partial q} = Q;$

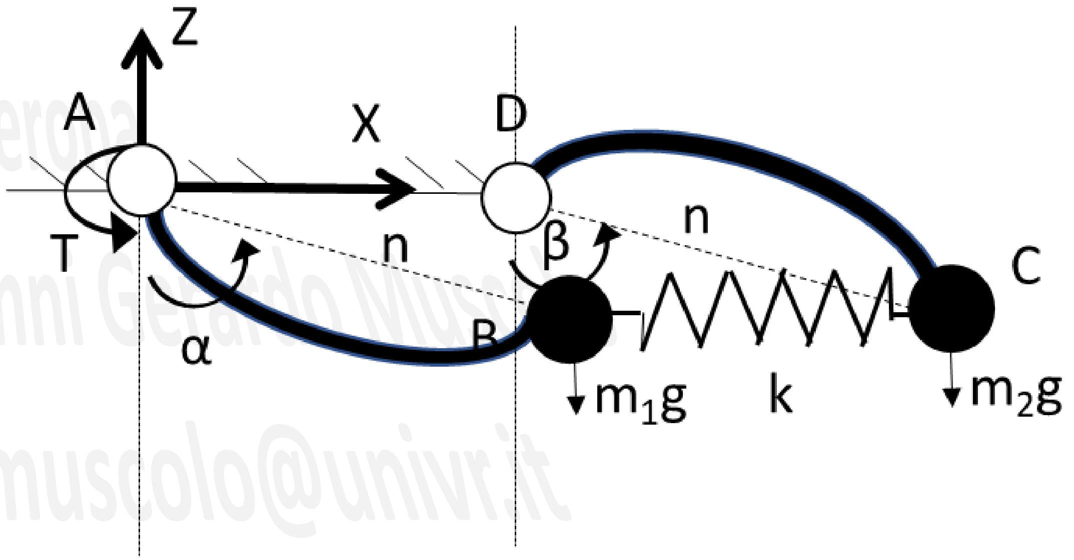
Exercise (Functional Design):

-) Lagrangian approach:

60) $\frac{d}{dt}\left(\frac{\partial E}{\partial \dot{q}}\right) - \frac{\partial E}{\partial q} + \frac{\partial U}{\partial q} = Q;$

61) $E = \frac{1}{2} m_1 n^2 \dot{\alpha}^2 + \frac{1}{2} m_2 n^2 \dot{\beta}^2;$

62) $U = -m_1 g n cos\alpha - m_2 g n cos\beta + \frac{1}{2} k n^2 (sin\alpha - sin\beta)^2;$



Exercise (Functional Design):

-) Lagrangian approach:

63) $\frac{d}{dt}\left(\frac{\partial E}{\partial \dot{\alpha}}\right) = m_1 n^2 \ddot{\alpha};$

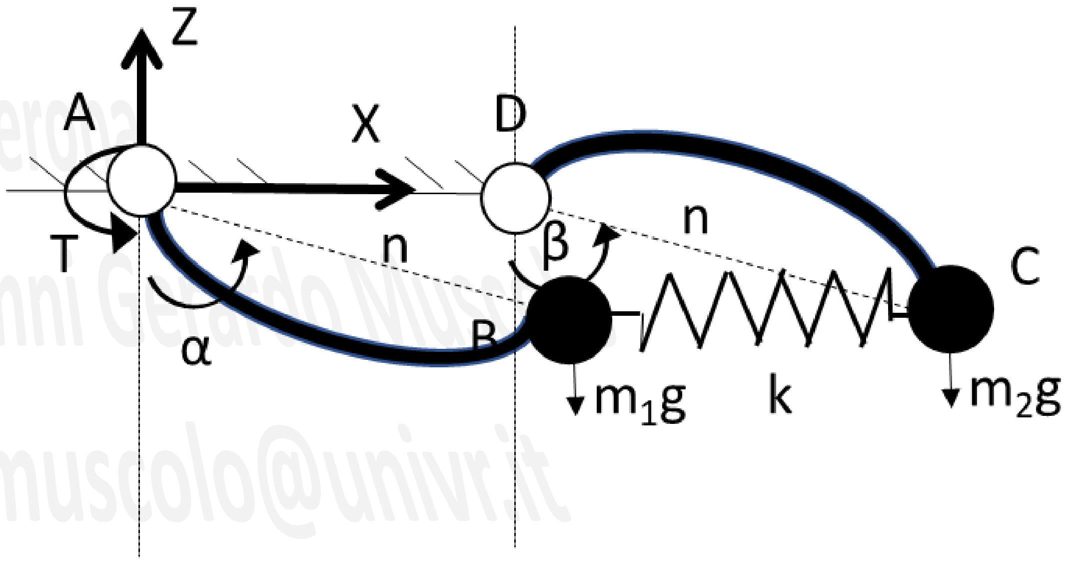
64) $\frac{d}{dt}\left(\frac{\partial E}{\partial \dot{\beta}}\right) = m_2 n^2 \ddot{\beta};$

65) $\frac{\partial E}{\partial \alpha} = \frac{\partial E}{\partial \beta} = 0;$

66) $\frac{\partial U}{\partial \alpha} = m_1 g n sin\alpha + k n^2 (sin\alpha - sin\beta) cos\alpha;$

67) $\frac{\partial U}{\partial \beta} = m_2 g n sin\beta - k n^2 (sin\alpha - sin\beta) cos\beta;$

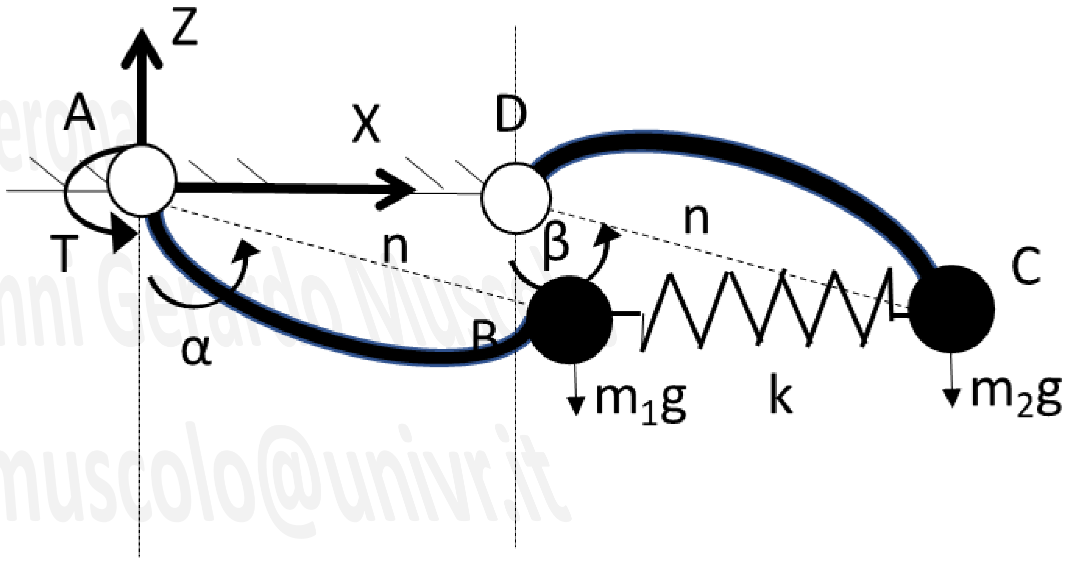
68) $Q = T;$



Exercise (Functional Design):

-) Lagrangian approach:

We will obtain the 58) and 59) using the Lagrangian's equation:

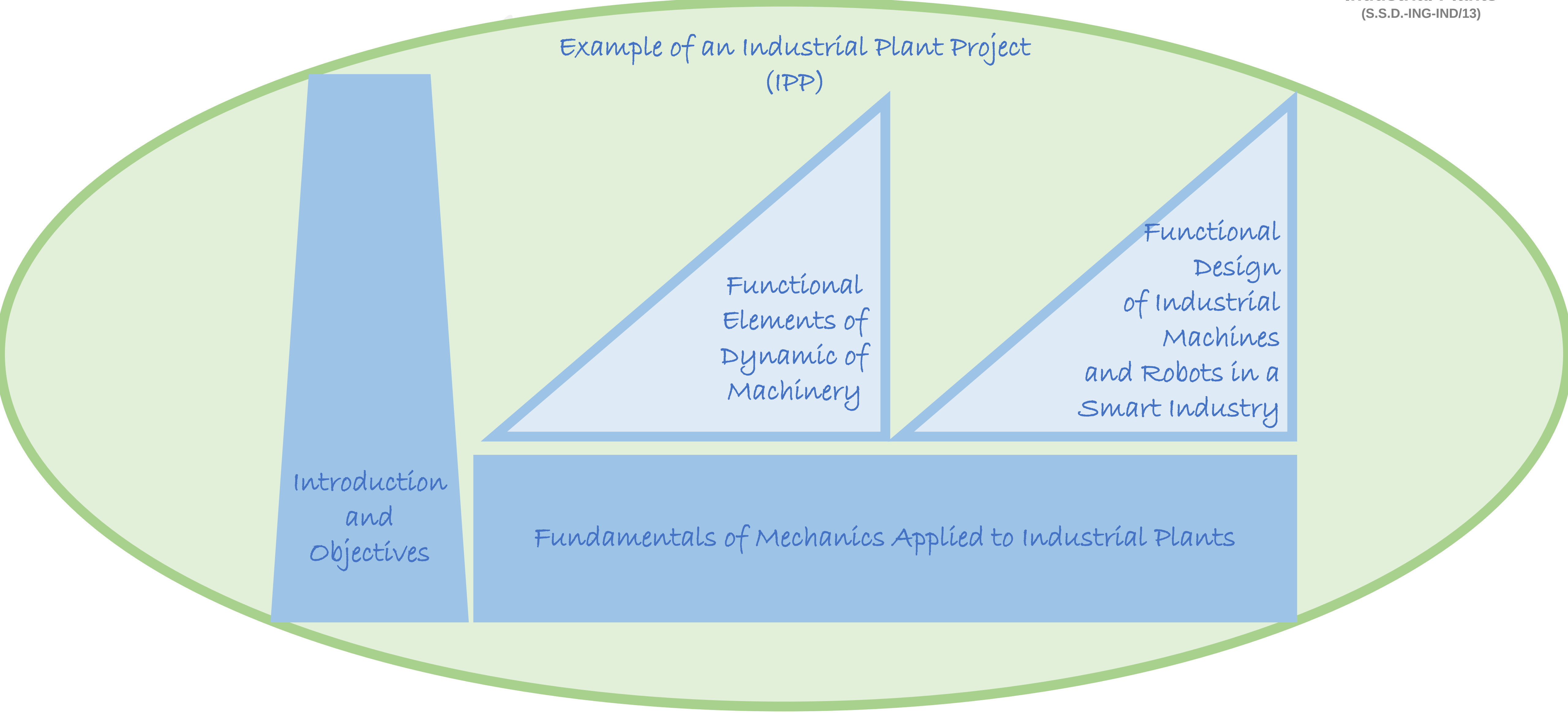


60) $\frac{d}{dt}\left(\frac{\partial E}{\partial \dot{q}}\right)-\frac{\partial E}{\partial q}+\frac{\partial U}{\partial q}=Q;$

58) $m_1n^2\ddot{\alpha}+kn^2(\alpha-\beta)+m_1gn\alpha=T;$

59) $m_2n^2\ddot{\beta}+kn^2(\beta-\alpha)+m_2gn\beta=0;$

Scheme of Industrial Plants



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