INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

FIMI – SCAN 2nd
Monday 16th December 2019

Mechanics – Test 2

Duration 1h (10h15-11h15)

Authorised: Formula sheets (1 page + 1 page for joints) and non-programmable calculator

Automotive steering system

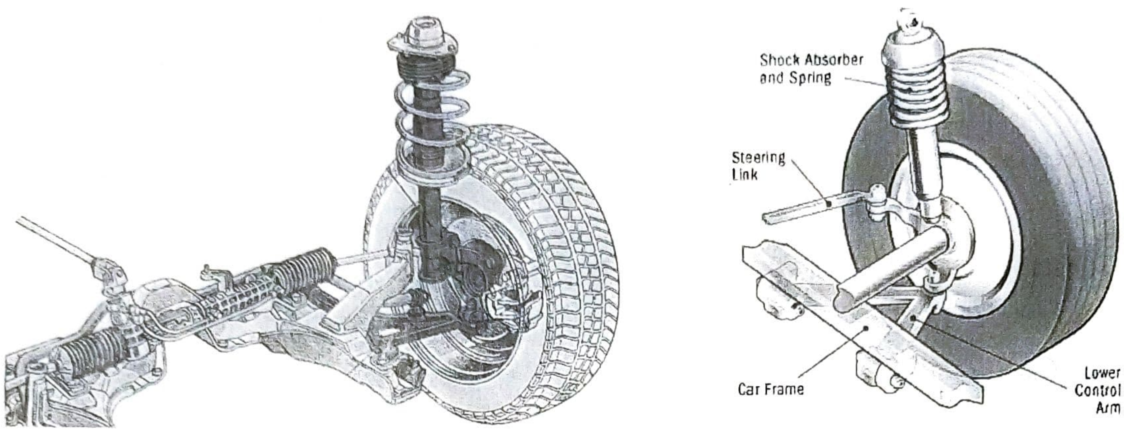

Figure 1 – Steering and suspension systems

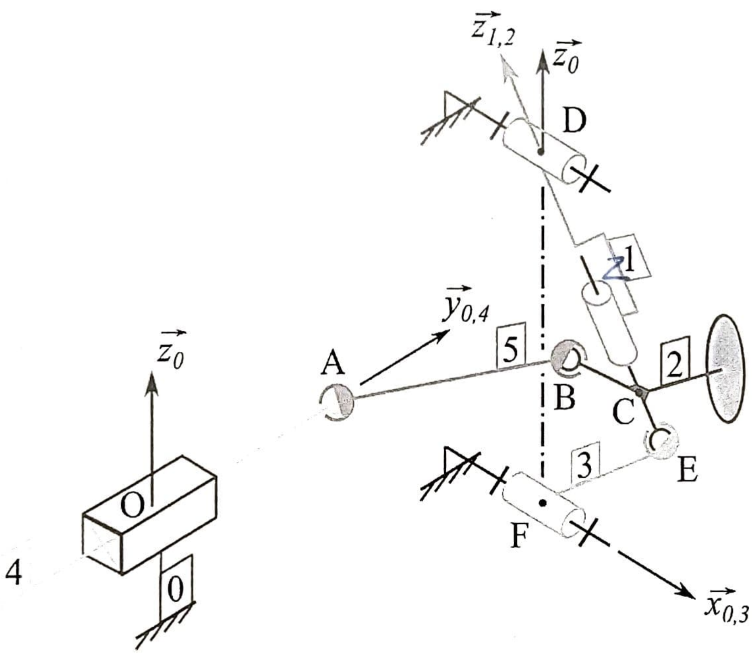

Figure 2 : Three-dimensional kinematic model

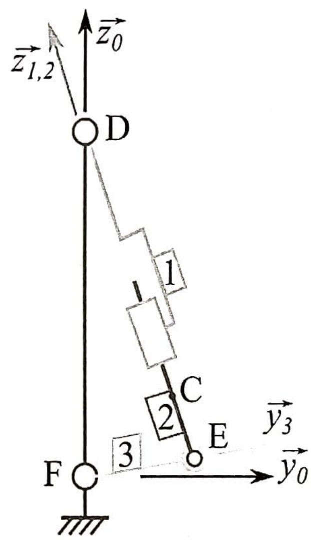

Figure 3 : Planar kinematic model DEF

Geometrical data

$AB = l$; $\overrightarrow{OD} = a\overrightarrow{y_0} + b\overrightarrow{z_0}$; $\overrightarrow{BC} = c\overrightarrow{x_2}$; $\overrightarrow{EC} = d\overrightarrow{z_2}$; $\overrightarrow{FE} = e\overrightarrow{y_3}$; $\overrightarrow{FD} = f\overrightarrow{z_0}$

The suspension (Mc Pherson type) and the steering system for an automotive front axle are shown in Figure 1 and the corresponding kinematic model is in Figure 2. It comprises :

- Damper body (1) connected to chassis (0) via a revolute joint of axis (D, $\overrightarrow{x_{0,1}}$).
  Motion parameter for 1/0 :$\alpha = (\overrightarrow{y_0}, \overrightarrow{y_1})$.
- Wheel frame (2) connected to damper (1) via a cylindrical joint of axis (D, $\overrightarrow{z_{1,2}}$).
  Motion parameter for 2/1 : $z = \overrightarrow{DC}.\overrightarrow{z_{1,2}}$ and $\beta = (\overrightarrow{x_1}, \overrightarrow{x_2})$.
- Oscillating arm (3) connected to chassis (0) via a revolute joint of axis $(F, \overrightarrow{x_{0,3}})$.
  Motion parameter for 3/0 : $\theta = (\overrightarrow{y_0}, \overrightarrow{y_3})$.
- Rack (4), whose displacement is controlled by the steering wheel rotation (not represented), is connected to chassis (0) via a prismatic joint of axis$(O, \overrightarrow{y_{0,4}})$.
  Motion parameter for 4/0 : $y = \overrightarrow{OA}.\overrightarrow{y_{0,4}}$

Moreover

The oscillating arm (3) is also connected to (2) via a spherical joint of centre E, with no parameter.

Rack (4) is connected to the wheel frame (2) via rod (5) with two spherical joints at A and B. No parameters are introduced for the two spherical joints and no physical frame is defined for (5).

Part I : Frame definition / Parameter definition / Constraint equations

I.1 - Give the graph of links.

I.2 - Give the change of basis diagrams.

I.3 - Develop the constraint equation(s) associated with the joint with no parameter between solids (2) and (3).

I.4 - Develop the constraint equation(s) associated with the joint with no parameter between solids 4 and 2, produced by the presence of rod (5). *Do not try to express one of the parameters in terms of the others*

I.5 - Give the degree of mobility of the system. Specify the motion(s) that are imposed in the real system.

Partie II : Kinematics

II.1 - Calculate the velocity and acceleration vectors of point E with respect to chassis (0), $\overrightarrow{V(E;/0)}$ and $\overrightarrow{A(E;/0)}$ in terms of kinematic parameter θ, and its time-derivatives along with geometrical data.

II.2 - Determine the velocities of point C with respect to 1, $\overrightarrow{V(C/1)}$, and for the motion of 1 with respect to 0, $\overrightarrow{V(C,1/0)}$.

II.3 - Determine the kinematic screw of 2/0 at point C.