MECHANICS – KINEMATICS

Test 3 – 2 hours

A two-page A4 personal formula sheet, tables with the classic joints and non-programmable pocket calculators are authorised.

Indicative marking scale – Section 1: /3.5; Section 2:/5; Section 3: /7; Section 4: /4.5

Sections 1+2, 3 and 4 are independent.

Analysis of a manual gearbox shift control system.

In automotive manual transmissions, the driver changes speed by moving a gear lever which operates the gearbox shift control system (Figure 1) which will be analysed from a kinematic viewpoint in this problem.

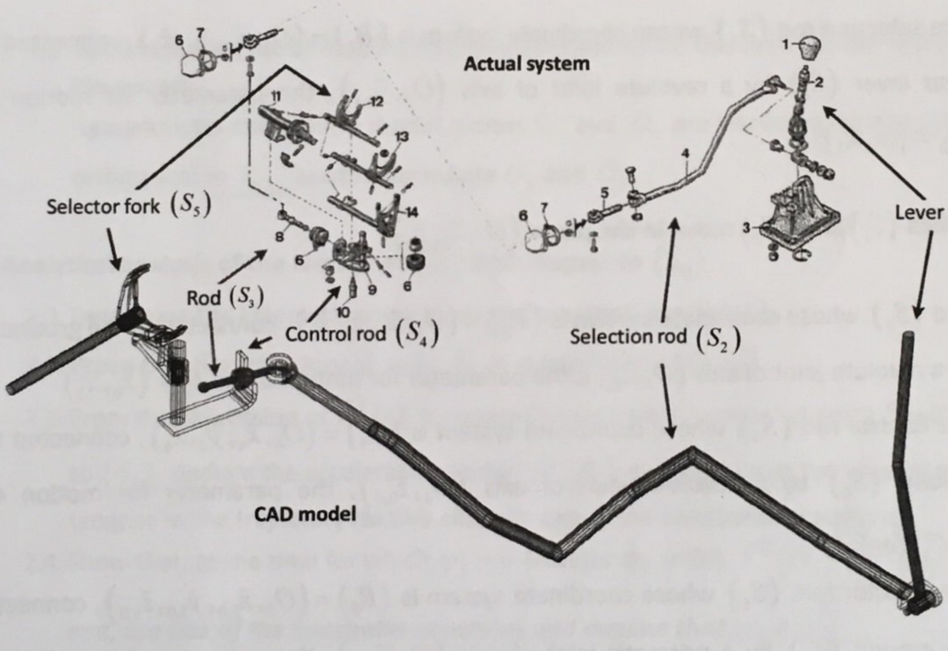

Figure 1 – Actual system and CAD model

The gearbox manual shift control system shown in Figure 1 is that used in Renault Clio 2. The technical drawing represents the main components of the system, i.e.

- The gear lever (S_1) operated by the driver to change gear
- The selection rod (S_2) which transfers the driver's action to the gearbox
- Rod (S_3) which controls either the choice of a reduction ratio or the engagement of a ratio,
- The control rod (S_4) which directly controls a selector fork

- A selector fork (S_5) which moves a pinion (not shown) corresponding to the desired speed ratio. There are as many forks as pairs of speed ratios (the CAD model in Figure 1 shows that associated with the 1st/2nd gear transition only).

In this problem, emphasis is placed on the engagement phase and, in order to simplify the analysis, it will be assumed that the mechanism can be decomposed into two successive planar mechanisms namely: a) the gear lever and the selection rod $(S_1)\cup(S_2)$ and, b) the assembly of the rod, control rod and fork $(S_3)\cup(S_4)\cup(S_5)$. The corresponding kinematic model is represented in Figure 2 and comprises (*Figs. 3 and 4 can also be helpful to understand the model*):

PARAMETERS!

- The vehicle chassis (S_0) (considered as the ground) whose coordinate system is $(R_0)=(O,\vec{x}_0,\vec{y}_0,\vec{z}_0)$.
- The gear lever (S_1) whose coordinate system is $(R_1)=(O_1,\vec{x}_1,\vec{y}_1,\vec{z}_1)$, connected to the ground (S_0) by a revolute joint of axis $(O_1,\vec{y}_{0,1})$, the parameter for motion 1/0 is $\psi_1=(\vec{x}_0,\vec{x}_1)$.
- The selection rod (S_2) whose coordinate system is $(R_2)=(O_2,\vec{x}_2,\vec{y}_2,\vec{z}_2)$, connected to the gear lever (S_1) by a revolute joint of axis $(O_2,\vec{y}_{2,1})$, the parameter for motion 2/1 is $\psi_2=(\vec{x}_1,\vec{x}_2)$.

Solids (S_1) and (S_2) move in the plane $(O\ ,\vec{x}_0,\vec{z}_0)$.

- Rod (S_3) whose coordinate system is $(R_3)=(O_3,\vec{x}_3,\vec{y}_3,\vec{z}_3)$, connected to the ground (S_0) by a revolute joint of axis $(O_3,\vec{z}_{0,3})$, the parameter for motion 3/0 is $\theta_3=(\vec{x}_0,\vec{x}_3)$
- The control rod (S_4) whose coordinate system is $(R_4)=(O_4,\vec{x}_4,\vec{y}_4,\vec{z}_4)$, connected to the ground (S_0) by a revolute joint of axis $(O_4,\vec{z}_{0,4})$, the parameter for motion 4/0 is $\theta_4=(\vec{x}_0,\vec{x}_4)$
- The selector fork (S_5) whose coordinate system is $(R_5)=(O_5,\vec{x}_{5,0},\vec{y}_{5,0},\vec{z}_{5,0})$, connected to the ground (S_0) by a prismatic joint of axis $(O_5,\vec{y}_{0,5})$, the parameter for motion 5/0 is $Y=\overrightarrow{OO_5}\cdot\vec{y}_{0,5}$

Solids (S_3), (S_4) and (S_5) move in the plane $(O\ ,\vec{x}_0,\vec{y}_0)$.

Moreover:

- the selection rod (S_2) and Rod (S_3) are connected by a linear-annular joint (with no parameter) of axis $(O_3,\vec{y}_3)$ passing through point B_2 attached to (S_2)

- Rod (S_3) and the control rod (S_4) are connected by a linear-annular joint (with no parameter) of axis $(O_3, \vec{y}_3)$ passing through point C_4 attached to (S_4)
- Finally, pin D_4 of the control rod (S_4) slides in the slot of solid (S_5) of axis $(O_5, \vec{x}_{0,5})$ (with no parameter)

The geometrical parameters are defined in Figure 2.

1 – Functional analysis of the mechanism

1.1 Give the graph of links

1.2 Give the vector form **without developing the expression** of the constraint equations associated with the joints with no parameters. Then, develop the analytical expression for the joint between (S_2) and (S_3) only to prove that one of the constraint equation reads:

$$a - b\cos\psi_1 - c\sin(\psi_1 + \psi_2) = 0$$

1.3 Deduce the degree of mobility of the system and relate this result to the functionality of the system.

Remark: note that, in this model, points C_4 and D_4 are implicitly located in the plane orthogonal to $\vec{z}_{0,3,4}$ containing points O_3 and O_5.

2 – Analytical analysis of the motion of (S_2) with respect to (S_0)

2.1 Determine the kinematic screw (sum and moment) at point O_2.

2.2 Prove that the trajectory of point B_2 is along the line $(O, \vec{x}_0)$.

2.3 From the expression of $\vec{V}^0(O_2)$, determine the velocity vector of point B_2 with respect to (S_0), deduce the acceleration vector $\vec{A}^0(B_2)$ and verify that the velocity vector is tangent to the trajectory (***to this end, use one of the constraint equations***)

2.4 Show that, at the time for which $\psi_1 = 0$ (***careful*** $\dot{\psi}_1 \neq 0$***!***), $\vec{V}^0(O_2) = \vec{V}^0(B_2)$ (***to this end, use one of the constraint equations and assume that*** $\psi_2 \neq \pm\frac{\pi}{2}$)

3 – Graphical analysis of the control system

All the developments in this section need to be clearly justified.

$\vec{V}^0(A)$, the absolute velocity of point A is given in Figure 3 **(to be handed in with your papers!)**

Motion of (S_2) with respect to (S_0)

3.1 Determine the velocity of point O_2 with respect to (S_0) and then derive that of B_2.

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1st Cycle -SCAN 2nd

24th January, 2018

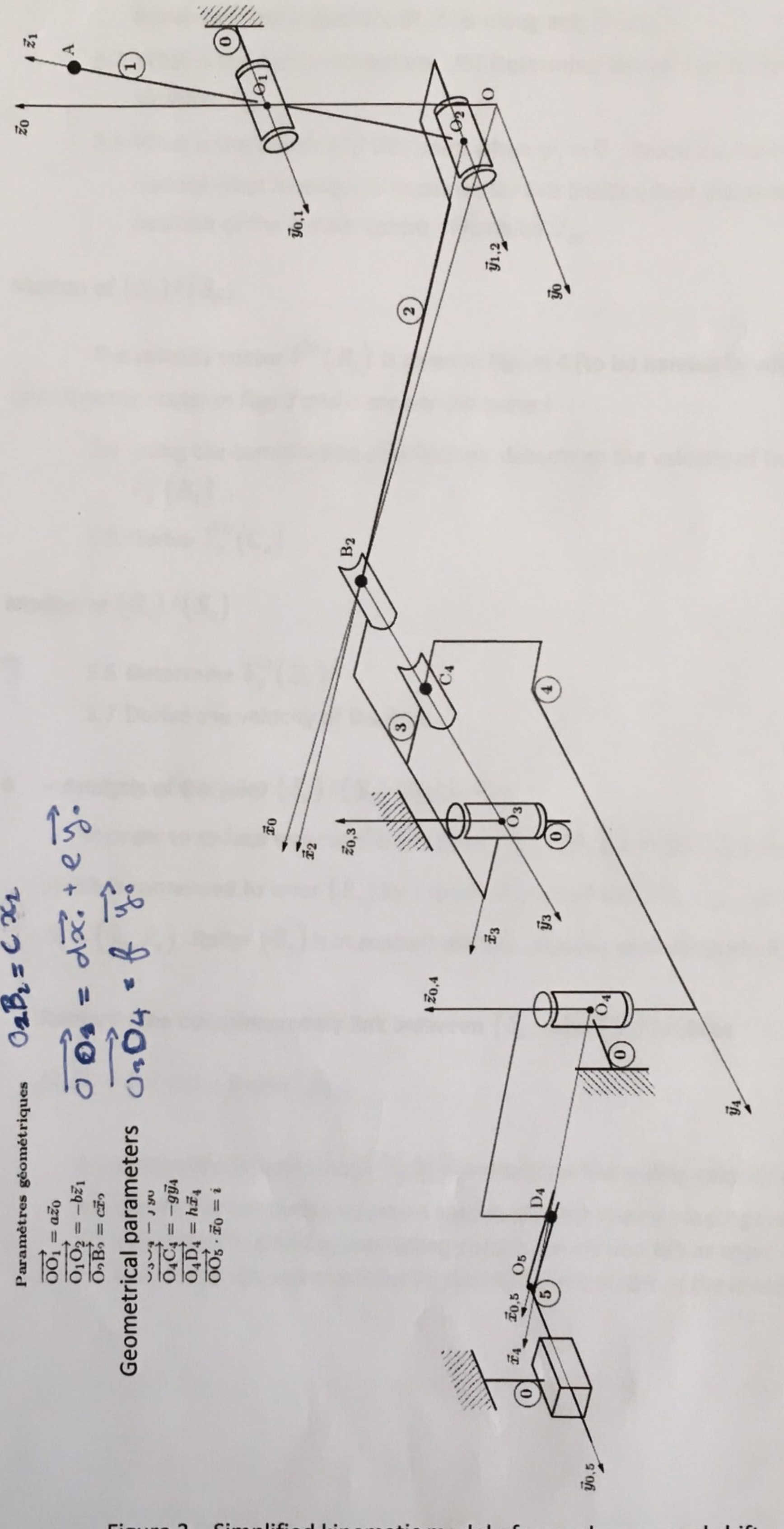

Figure 2 – Simplified kinematic model of a gearbox manual shift control system