INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

Tuesday 27th January, 2015

SCAN 2nd

Kinematics Exam

Windscreen wiper mechanism of Renault Scénic II

Duration: 3 hours

Authorised documents: A4 personal formula sheet + table of the usual links

The different parts of the exam are independent.

Presentation

The proposed analysis focuses on the (front) windscreen wiper mechanism of the Renault Scénic II which, as an important security element, must comply with the European directive 78/318/CEE.

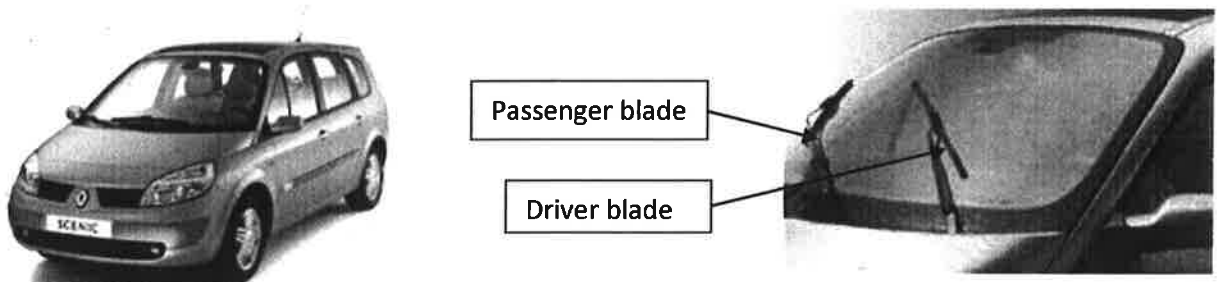


Figure 1

A windscreen wiper mechanism comprises an electric motor and a mechanical transmission (see figure 2), which transforms the continuous rotation of the motor into the periodic motions of the two wiper blades.
In what follows, the curvature of the windscreen is neglected and all the motions are considered as planar.

The mechanical transmission in Figure 2 is decomposed into 3 sub-systems for which all the joints are revolute joints:

a- The primary transmission: Similar to a crank-rod system, it transforms the continuous rotation of the motor-reducer shaft (crank 1) into the alternative rotation of the driver windscreen wiper blade 3, via rod 2.

b- The intermediate transmission which transfers the motion of blade 3 (driver side) to the passenger blade. It is composed of rod 4 and crank 5.

c- The secondary transmission: A so-called *'four-bar system'* which operates the passenger blade 7 using crank 5 and lever 6.

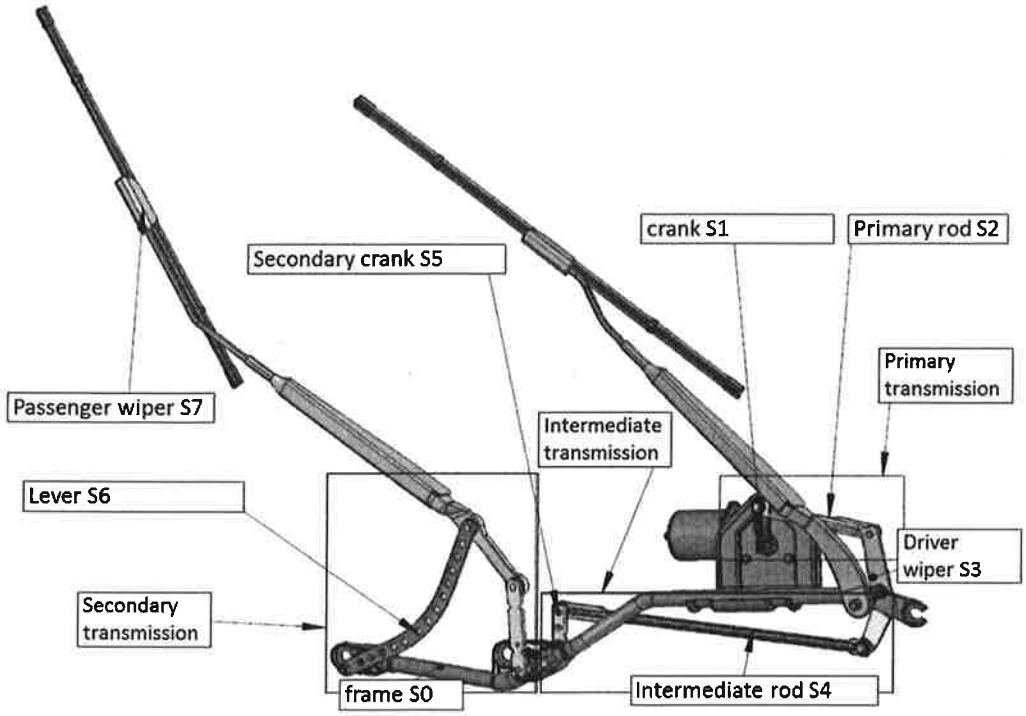


Figure 2

1. Blade orientation

The objective of this part is to determine the angles of the driver windscreen wiper blade 3 and that of the passenger (solid 7) in terms of the input angle of crank 1.

Annex 1 shows the frame definition of the planar system with: $\vec{x}_1 = \frac{\overrightarrow{AB}}{\|\overrightarrow{AB}\|}$; $\vec{x}_4 = \frac{\overrightarrow{FE}}{\|\overrightarrow{FE}\|}$; $\vec{y}_7 = \frac{\overrightarrow{LM}}{\|\overrightarrow{LM}\|}$; $\vec{y}_3 = \frac{\overrightarrow{ED}}{\|\overrightarrow{ED}\|} = \frac{\overrightarrow{DC}}{\|\overrightarrow{DC}\|}$ (E, D and C are aligned) ; $\vec{y}_5 = \frac{\overrightarrow{KF}}{\|\overrightarrow{KF}\|} = \frac{\overrightarrow{FL}}{\|\overrightarrow{FL}\|}$ (K, F and L are aligned).

All the joints are assimilated to perfect revolute joints of axis $\vec{z}$ perpendicular to the plane $\left(N, \vec{x}_0, \vec{y}_0\right)$.

The table (*here ->*) specifies the positions and parameters of all the joints (links) (<u>please note that all the angles are defined from vectors of the coordinate system 0!</u>).

Link	Point	Parameter
1/0	A	$\varphi_1 = \left(\vec{x}_0, \vec{x}_1\right)$
3/0	D	$\varphi_3 = \left(\vec{y}_0, \vec{y}_3\right)$
4/5	F	$\varphi_4 = \left(\vec{x}_0, \vec{x}_4\right)$
5/0	K	$\varphi_5 = \left(\vec{y}_0, \vec{y}_5\right)$
7/5	L	$\varphi_7 = \left(\vec{y}_0, \vec{y}_7\right)$

The following joints have no parameters:

- The revolute joints at points B and C between rod <u>2</u> and solids 1 and 3 respectively.
- The revolute joint at point E between solids 3 and 4.
- The revolute joints at points M and N between rod 6 and solids 7 and 0.

The constant distances are defined in Annex 1.

Questions:

1.1. Draw the graph of links and change of basis diagrams.

1.2. In the primary transmission :
Determine the relationship(s) between the input and output parameters φ_1 and φ_3 in terms of geometrical parameters. *Do not try to express φ_3 in terms of φ_1.*

1.3. In the intermediate transmission:

1.3.1. Determine the relationship(s) between the input and output parameters φ_3 and φ_5 in terms of geometrical parameters. *Do not try to express φ_5 in terms φ_3.*

1.3.2. Supposing that $c = k$ leads to $\varphi_5 = -\varphi_3$ and that $y_k - 2c\cos\varphi_3 << x_k$, find the particular motion 4/0 can be assimilated to. Specify its characteristics.

1.4. In the secondary transmission:
Give the constraint equation(s) associated with the secondary transmission. *Do not develop it (them)!*

2. Speed of the blades

The objective of this second part is to verify that the maximum speed at the blade outer tip is less than the limiting speed of 7 m.s^{-1} imposed by the European Standard (in order to have good evacuation of the water from the windscreen).

Questions :

2.1. Define precisely the trajectories of points C, E, P, F, L and M in their motions with respect to S_0.

2.2. The velocity at the extremity P of the driver blade with respect to 0 is represented in Annex 2 which shows the planar mechanism in a particular configuration.

- Using annex 2, deduce by graphical means the velocity vector at the extremity Q of the passenger blade with respect to 0. Precise and concise explanations are required.
- If the magnitude of the velocity of P / 0 is 5 m.s^{-1}, what is that at point Q? Is it compatible with the limit imposed by the standard for the configuration under study?

2.3. Determine analytically the expressions of :

- the velocity and acceleration vectors at P with respect to 0, in terms of φ_3 and its time-derivatives ;
- the velocity and acceleration vectors at Q with respect to 0, in terms of φ_5 and φ_7, and their time-derivatives.

2.4. Determine by analytical means the position of the instant centre of rotation in the motion 7/0 I_{70} with respect to point K, in terms of $\dot{\varphi}_5$ and $\dot{\varphi}_7$.
Reminder: the instant centre of rotation is the intersection of the kinematic wrench central axis and the plane of the figure.

3. Statics

Preliminary remark: The Renault Scénic II is equipped with flexible wiper blades so that the contact pressure (and the normal force) between the blades and the windscreen is uniformly distributed (§3.2). Supposing that the friction coefficient is constant all along the blade-windscreen contacts, the friction forces are also uniformly distributed along the blade (§3.1). In this section, the windscreen will be denoted WS.

3.1. Estimation of the input torque (graphical statics)

The objective is to evaluate the input torque needed to operate the two wiper blades in the configuration shown in Annex 3. Dynamic effects are neglected compared with the forces at play so that a static analysis can be performed.

Gravity (weights) are also neglected and only the tangential contact (friction)forces between the windscreen and thee blades all in the plane $\left(N, \vec{x}_0, \vec{y}_0\right)$, are considered; : these friction forces counterbalance the input torque and are modelled as two sliding vectors $\{F_{WS/7}\}$ and $\{F_{WS/3}\}$ as represented in Annex 3 such that:

- Their sums are denoted $\vec{T}_{WS/7}$ and $\vec{T}_{WS/3}$ respectively;
- Both their amplitudes (norms) are 20N ;
- Their lines of action are perpendicular to the blades and pass through the mid-point of each blade (in agreement with the preliminary remarks above).

All the joints are perfect revolute joints.

Questions: *Please, justify your graphical construction in your paper.*

3.1.1. Starting from the sliding vector $\{F_{WS/7}\}$ and isolating the proper members, find the sliding vector $\{F_{4/3}\}$ passing through point E.

3.1.2. Show that the wrench equivalent to the two sliding vectors $\{F_{WS/3}\}$ and $\{F_{4/3}\}$ is also a sliding vector.

Give the line of action and amplitude of this equivalent sliding vector. Represent it in Annex 3.

Deduce the sliding vector $\{F_{2/3}\}$ by isolating the driver blade 3 (now considered as a three-force member).

3.1.3. The length of crank AB is 60 mm, calculate the input torque (for the position in the figure $\vec{AB}$ and $\vec{BC}$ are perpendicular).

3.2. Selection of the wiper blade spring (analytical statics)

The 'pressing' force for each wiper blade onto the windscreen (around 25 N) is generated by a spring for the most part whereas the contribution of aerodynamic forces generally remains of secondary importance.

Annex 4 represents a wiper blade at rest in the vertical plane (cross section of the windscreen) with $\vec{z}_0$, the normal to the windscreen plane. The wiper blade comprises solids S3, S31 and S32, connected by perfect revolute joints at O_3 and O_3^*, of direction $\vec{x}_{0,0*}$; the revolute joint at D is that in Annex 1.

The objective in this section is to determine the expression of the force per unit contact length $\vec{f}_{WS/32} = f_{WS/32}\vec{z}_0$ ($f_{WS/32}$ in N/m) in terms of the stiffness k of the spring and the system geometrical parameters.

It is supposed that the windscreen exerts the following force wrench on the wiper blade

$$\{F_{WS/32}\} = \begin{cases} \vec{R}_{WS/32} = F_{WS/32}\vec{z}_0 \\ \vec{M}_{WS/32}(O_3^*) = M_{WS/32}\vec{x}_0 \end{cases}$$ where $F_{WS/32}$ and $M_{WS/32}$ are unknown.

Data (see Annex 4):

- One defines $\vec{y}_0^* = \dfrac{\overrightarrow{O_3O_{3*}}}{\|O_3O_{3*}\|}$ and $\beta = (\vec{y}_0, \vec{y}_0^*)$
- The spring is the direction $\vec{y}_0$, its stiffness is k, its actual length is $O_RO_R^* = \ell$, its length at rest (initial length when unloaded) is ℓ_0. In such condition, the force exerted by the spring onto solid 31 is $\vec{F}_{Spring/31} = -k(\ell - \ell_0)\vec{y}_0$ applied at O_R^*.
- The length of blade S32 = L ; O_3^* is located at the middle of the wiper blade.
- $O_3O_R^* = O_3^*O_R^* = d$.

Questions :

3.2.1. Determine the actual length of the spring l in terms of β .

3.2.2. For a uniform pressure distribution from the windscreen onto the wiper blade, give the sum the force wrench in terms of $f_{WS/32}$.

3.2.3. Expressing all the mechanical actions in the coordinate system $(\vec{x}_0, \vec{y}_0, \vec{z}_0)$, develop the equilibrium equations for $S_{31} \cup S_{32}$

3.2.4. Deduce the expression of $f_{WS/32}$ in terms of the spring stiffness k and the geometrical parameters.

4. Belt transmission

In this part of the problem, rod 6 is eliminated and motion is transmitted between solid 5 and solid 7 by a belt system (cf. Annex 5):

- The first pulley of centre K and radius R_0 is fixed to the ground 0 ; the belt c is tangent to this pulley at point I ;
- The second pulley of centre L and radius R_7 is fixed to solid 7; the belt c is tangent to the second pulley at point J.

Hypotheses:

- The part of the belt c between I and J is supposed to behave like a rigid bar and its motion can be assimilated to a translation with respect to 5.
- There is no slipping at I and J ;
- It will be assumed that $\overrightarrow{KI}$ and $\overrightarrow{LJ}$ are both in the $\vec{x}_5$ direction.

The motion parameters are the same as in the rest of the text:

- The parameter for motion 5/0 is $\varphi_5 = (\vec{y}_0, \vec{y}_5)$
- The parameter for motion 7/0 is $\varphi_7 = (\vec{y}_0, \vec{y}_7)$.

Questions:

4.1. Develop the no slipping conditions at I and J.

4.2. Justify the fact that we must have $\vec{V}(I, c/5) = \vec{V}(J, c/5)$.

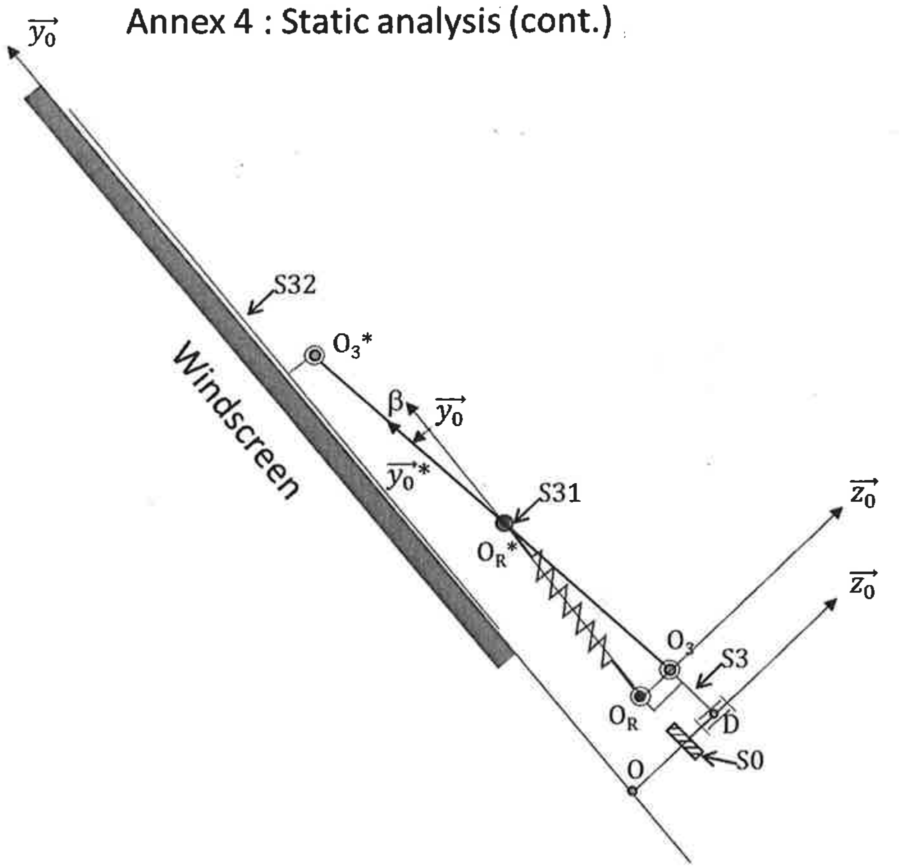
4.3. Using the velocity combination, deduce the relationship between the angular speeds $\dot{\varphi}_5$ and $\dot{\varphi}_7$.

4.4. Determine the speed ratio $\dot{\varphi}_7 / \dot{\varphi}_5$.

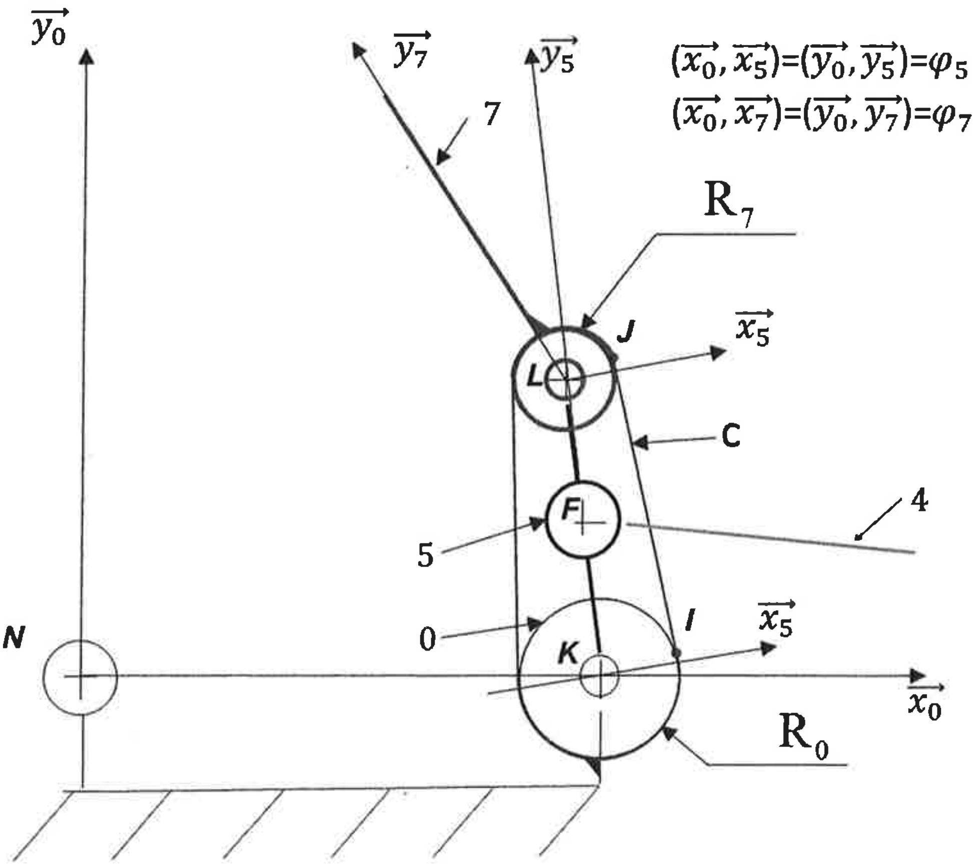
- considering $R_0 > R_7$; do both wiper blades 3 and 7 rotate in the same sense (annex 1) ?
- considering $R_0 = R_7$; characterise the motion of 7 with respect to 0.

4-5 Calculate the rolling and pitching vectors at points I and J in terms of $\dot{\varphi}_5$ and $\dot{\varphi}_7$

Annex 4 : Static analysis (cont.)



Annex 5 – Belt transmission



Annex 3 – Graphical force analysis **Name :** **Group :**