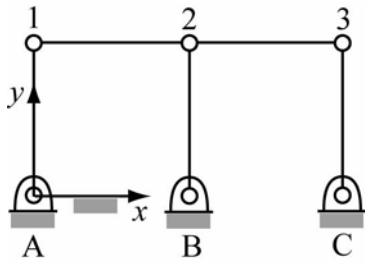
DOUBLE FOUR-BAR MECHANISM

The figure shows a double four-bar mechanism with all the links having length of 1 m and uniformly distributed mass of 1 kg. When the mechanism reaches the horizontal position, the number of degrees of freedom instantaneously increases from 1 to 3. Therefore, this benchmark problem is proposed as an example of multibody system going through singular positions.



The gravity force acts in the negative vertical direction, with a value of 9.81 m/s^2. Initially, the position of the system is the one shown in the figure, and the velocity of any of the three mobile pins (points 1, 2 or 3) is 1 m/s to the right. The total time of simulation is 10 s.

Figure 1 shows the histories of the *x*-coordinate of point 1 and its time derivative during the simulation.

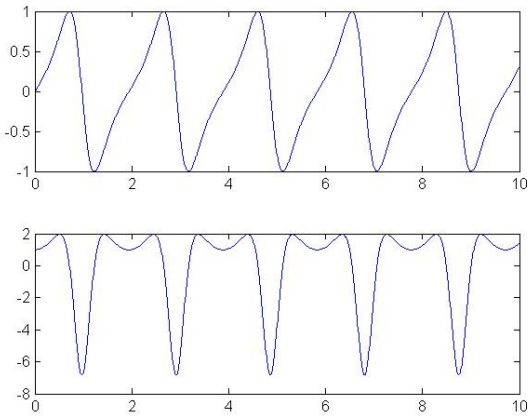


Figure 1: Histories of x_1 and $\dot{x}_1$.

Figure 2 gathers the histories of the total energy and the constraints violation at position, velocity and acceleration levels.

The total energy is obtained as the sum of the kinetic and potential energy of the mechanism, taking the initial total energy as reference, so that the energy value to be conserved during the simulation is zero. The error of the simulation will be considered as the maximum drift of the energy from its theoretical null value.

On the other hand, the represented constraints violations in Fig. 2 are, respectively, the norm of the constraints vector and its first and second derivatives. Of course, these magnitudes will not be present in case the applied formulation is based on independent coordinates.

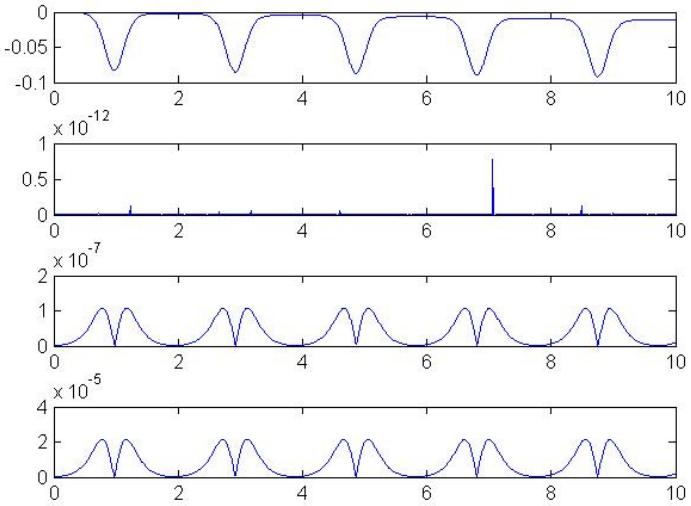


Figure 2: Histories of the total energy and the constraints violation at position, velocity and acceleration levels.

The objective of this benchmark problem is to carry out the simulation in the minimum possible CPU time, being the error (maximum drift of the total energy along the simulation) below 0.1 J.

A text file containing the results is also available, so that other researchers may compare them with those obtained through their own methods. The file has got seven columns, the first one being the simulation time from 0 to 10 s, with an increment of 0.01 s. The second column provides the value of x_1 in m, the third column provides the value of $\dot{x}_1$ in m/s, the fourth column provides the value of the total energy in J, and the last three columns provide the values of constraints violation at position, velocity and acceleration levels, respectively.