

# MBS Benchmark A04: Bricard's Mechanism

## Benchmark Objective

Bricard's mechanism (benchmark problem **A04**) [1] is an example of over-constrained system. Grübler's formula [2] results in no degrees of freedom, however, the particular orientation of the revolute pairs results in a system with 1 degree of freedom.

## Benchmark Description

The system is composed of five rods and six revolute joints. Gravity is acting in the negative  $y$  direction.

Tab. 1 reports system properties.

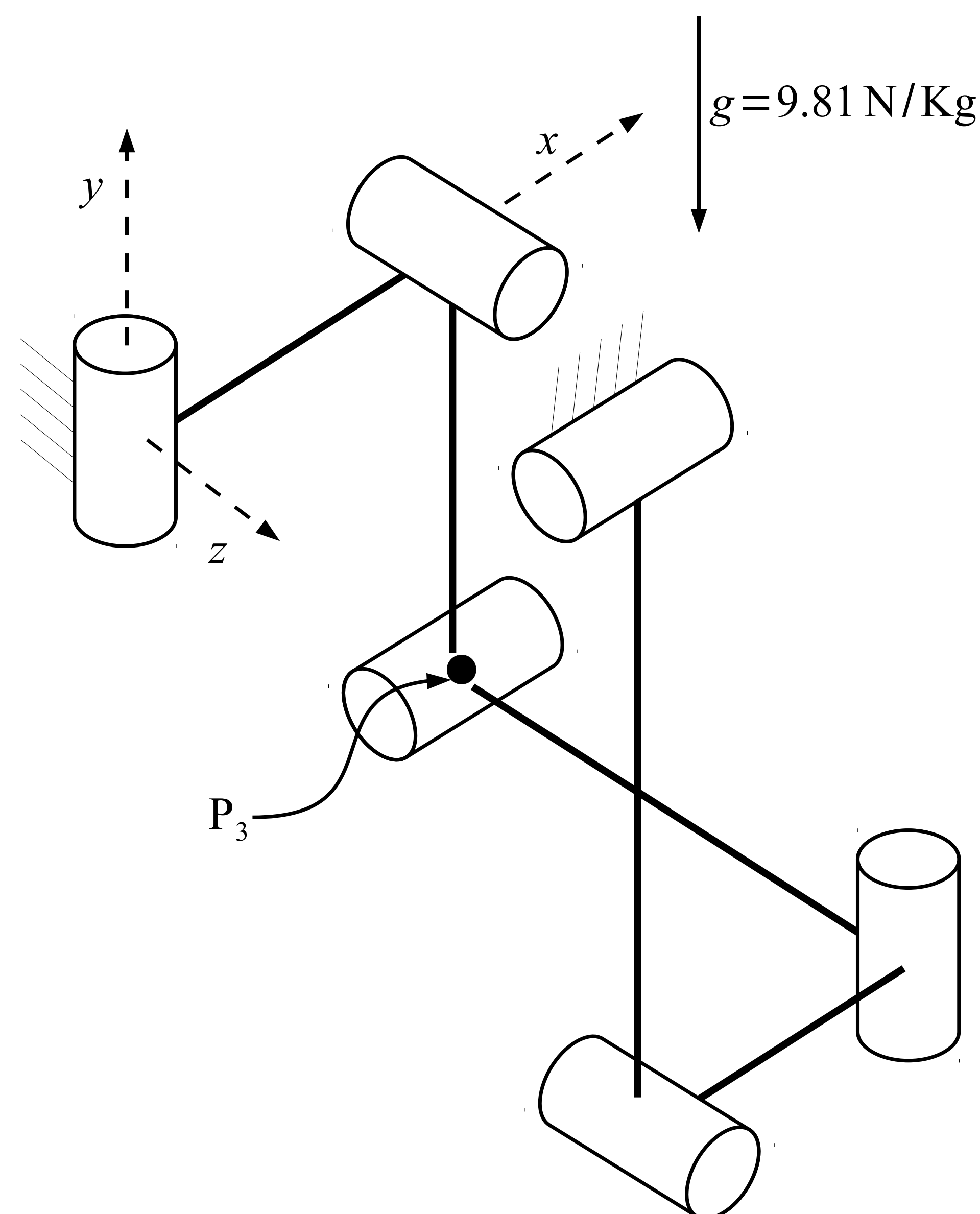


Figure 1: Bricard's mechanism sketch.

Rods mass	1.0 kg
Rods length	1.0 m

Table 1: System Properties and Configuration

## Results

The dynamic simulation of the **A04** benchmark was executed for 600s. Fig. 1 shows the Bricard's Mechanism in its initial position.  $P_3$  displacements estimated with the OpenSim simulation are compared with the values provided as reference [3].

Fig. 2 shows the outputs of OpenSim-based simulation and the benchmark references [3] for a 10s period.

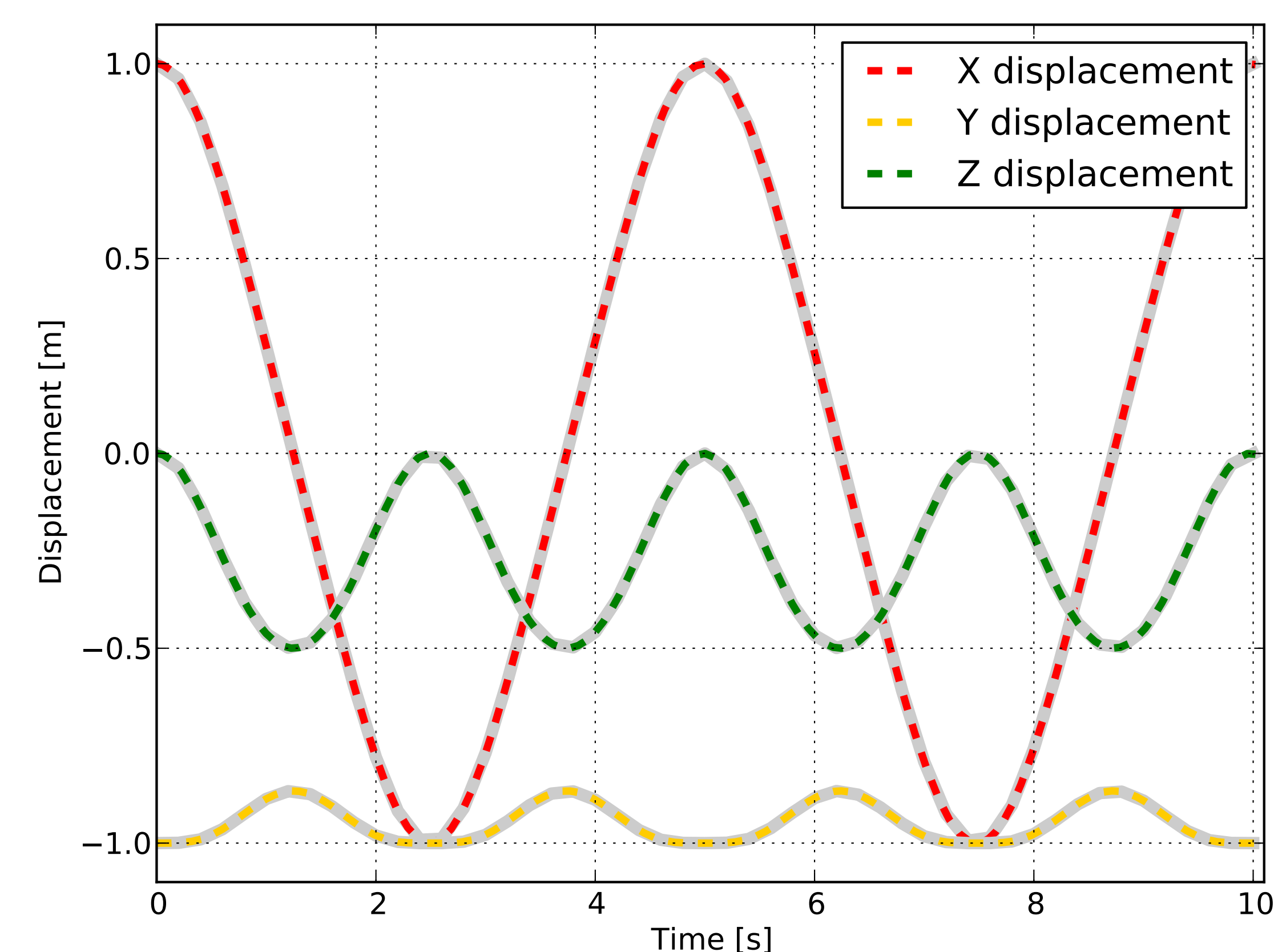


Figure 2:  $P_3$  displacements in OpenSim simulation (dashed lines) and MBS benchmark reference values (gray lines).

## Download

- MBS Benchmark available at: <http://goo.gl/ySQ5me>
- OpenSim implementation available at: <http://goo.gl/R9t13z>
- Videos of OpenSim simulation available at: <http://goo.gl/8RF6nR>

## References

- [1] Bricard R. "Mémoire sur la théorie de l'octaédre articulé", in Journal de Mathématiques pures et appliquées, Liouville 3, 1897, pp. 113–148.
- [2] M. Grübler, "Allgemeine Eigenschaften der zwangläufigen ebenen kinematischen Ketten," Ed. Simion, 1884.
- [3] M. González, D. Dopico, U. Ligris, J. Cuadrado, "A benchmarking system for MBS simulation software: Problem standardization and performance measurement", in Multibody System Dyn., vol. 6, no.2, 2006, pp. 179–190.

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