# wb1413
# Multibody Dynamics B

Spring Term 2013, Thu 15:45-17:30, room CT-CZ G, 4 ECTS credits.

## Homework assignment 10

A simple mechanical model of the human arm consists of two rigid bodies connected by three hinges. The space fixed coordinate system is, seen from a human perspective looking straight ahead North, the $z$-axis up, the $y$-axis North, and the $x$-axis East. The arm is an open loop structure with, starting from the torso, a hinge with an angle $\alpha$ about the $x$-axis, a hinge with an angle $\beta$ about the $y$-axis, the upper arm with length $d = 30$ cm in the minus $z$-direction, a hinge with an angle $\gamma$ about the $x$-axis, and finally the lower arm with length $e = 40$ cm in the plus $y$-direction. The location of the imaginary hand at the endpoint is now $(0, e, -d)$ with all angles $\alpha$, $\beta$, and $\gamma$ equal to zero. The upper arm has a concentrated mass of $m_d = 3$ kg at a distance $d/3$ from the shoulder whereas the lower arm has a concentrated mass of $m_e = 3$ kg at $e/2$ from the elbow. We neglect the mass moments of inertia. We assume gravity to work in the minus $z$-direction with a field strength of $g = 9.81$ N/kg.

a. Make a sketch of the model, use cans-in-series to depict the hinges.

b. Derive the equations of motion for the arm in terms of the independent degrees of freedom $\alpha$, $\beta$, and $\gamma$, and check your results for some simple configurations where you can predict the resulting accelerations of the degrees of freedom.

c. Picture a ball catch posture given by $(\alpha, \beta, \gamma) = (110°, -20°, -20°)$. Determine the three hinge Torques necessary to maintain this posture.

d. Check your result by means of a forward dynamic analysis of the system for a time period of 5 seconds (copy and paste the torques from item (b)). Discuss the accuracy and stability of the solution.