Aufgabe 5

1. ***Minimum and Maximum Torques***

G(q) represent the torques that need to be applied to arm’s Joint to compensate Gravity force

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* All torques are near zero because the force of gravity acts straight down
* The robot doesn’t need much effort to hold this position

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* Joint 2 (53.6 Nm) needs a lot of torque because it supports the entire weight of the extended arm
* Joint 4 (-14.6 Nm) has significant torque because it balances part of the arm’s weight.

Torque increases when gravity has more leverage (longer lever arm)

If the robot arm is **pointing straight down**, gravity pulls, but **it doesn’t create much rotation**, so torque is smaller

1. ***Mass Matrix***

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**Structure of the Mass Matrix**

The elements of the matrix describe:

**Diagonal elements** → The **inertia** of each joint. Higher values mean the joint resists changes in motion more

**Off-diagonal elements** → Coupling effects between joints. A nonzero value means motion in one joint affect another

* **Configuration 1: Vertical (Home Position)**

1. The **first joint (shoulder)** has a **very low inertia (0.0848 kg·m²)** since it's almost aligned with gravity.
2. **Joint 2 (3.4155 kg·m²)** has the **highest inertia**, meaning it's carrying most of the mass.
3. **Joint 4 is heavily coupled to Joint 2** (-1.1723), meaning movement in Joint 4 affects Joint 2 significantly

* **Horizontal Configuration (Arm Extended)**

1. **Joint 2 and Joint 4 still have strong coupling** (M24​=−1.1723).
2. **Other joints have almost no coupling (off-diagonal elements are very small or zero).**

Means the joints move more independently when the arm is fully extended.

* **Intermediate Configuration**

1. Joint 1 and Joint 4 now have noticeable coupling (M14 = 0.5773)
2. Joint 2 and Joint 4 still show strong coupling (M24 = -0.8285)
3. Coupling is more distributed compared to the horizontal configuration.

**Interpretation :**

* Joint 2 and Joint 4 are strongly coupled in all configurations. When Joint 2 moves, it affects Joint 4, and vice versa.
* In the horizontal position, joints are more independent because most off-diagonal elements are nearly zero.
* In the intermediate configuration, coupling is more complex, meaning movements in one joint influence more joints.
* The coupling stays the same for each configuration while the diagonal elements Mass values change because of the impact of gravit.force lever\_law

1. ***generalized Euler and Coriolis forces for different joint velocities***

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***q = [0.3; -0.5; 0.3; -0.1; 0.7; -0.4; 0.5];***

***q\_dot = [1.4834; 1.4834;1.7452;1.3089;2.2688 ;2.356;2.356];***

***q\_ddot = [0.5; 0.2; -0.3; 0.1; 0.4; -0.2; 0];***

***Coriolis Forces***

***-2.3343***

***3.9868***

***0.0907***

***-1.7216***

***0.0304***

***0.0132***

***0.0058***

***Euler Forces:***

***0.4026***

***0.5725***

***-0.0217***

***-0.0904***

***0.0064***

***-0.0061***

***0.0004***

***1.2. joints have the most coupling effect. in different velocities configurations,***

1. ***Untersuchen Sie den Effekt von externen***

***An application of Force has a resulting vector of joints torque :***

***While the robot configuration is as following***

***q = [0.1; -0.5; 0.3; -0.1; 0.2; -0.4; 0.5];***

***F\_ext = [0; 5 ; 0; 0; 0; 0]; force in Y direction***

***Joint torques due to external force:***

***-0.0000***

***4.9750***

***-0.2393***

***-4.6234***

***-0.0496***

***4.1531***

***-1.1297***

After taking the main axis from the joint’s in URDF file into consideration.

It appears that a force in Y direction affects the joints with the corresponding main axis

The most. (Joint 2,4,6 rotate in the Y axis).

The last Joint Torque 7 is relatively bigger, although it rotates around the Z axis, which is probably due to the fact that’s near to force source application.

1. ***Werden Reibungsmomente im dynamischen Modell berücksichtigt***

The Friction is not included in the RBT from MATLAB.

Which means, we will have to add it separately if we want to model the impact of the friction force on the robot arm