Exercise 4.1

1. Derive the equations of motion of the robot arm considered in the last lecture by using LagrangeD'Alembert's Principle (MATLAB or other software can be used). Note information about the kinematics and link masses is available here: https://www.universal-robots.com/articles/ur/application-installation/dh-parameters-for-calculations-of-kinematics-and-dynamics/

2. What joint torques (τ_1, τ_2, τ_3) should be applied to the joints for holding the arm at a configuration $\boldsymbol{q} = (\theta_1, \theta_2, \tau_3) = (1, \pi/3, \pi/3)$.

3. Simulate the robot arm by using `ode45` with input $\boldsymbol{Q} = (\tau_1, \tau_2, \tau_3) = -D\boldsymbol{q}$, where D is a diagonal matrix. Use initial condition $\boldsymbol{q} = (\theta_1, \theta_2, \theta_3) = (1, \pi/3, \pi/3)$.

The inertia tensors of the links are

$$I_1 = \begin{bmatrix} 0.0084 & 0 & 0 \\ 0 & 0.0064 & 0 \\ 0 & 0 & 0.0084 \end{bmatrix}, I_2 = \begin{bmatrix} 0.0078 & 0 & 0 \\ 0 & 0.21 & 0 \\ 0 & 0 & 0.21 \end{bmatrix}, I_3 = \begin{bmatrix} 0.0016 & 0 & 0 \\ 0 & 0.0462 & 0 \\ 0 & 0 & 0.0462 \end{bmatrix},$$

$$I_4 = \begin{bmatrix} 0.0016 & 0 & 0 \\ 0 & 0.0016 & 0 \\ 0 & 0 & 0.0009 \end{bmatrix}, I_5 = \begin{bmatrix} 0.0016 & 0 & 0 \\ 0 & 0.0016 & 0 \\ 0 & 0 & 0.0009 \end{bmatrix}, I_6 = \begin{bmatrix} 0.0001 & 0 & 0 \\ 0 & 0.0001 & 0 \\ 0 & 0 & 0.0001 \end{bmatrix},$$