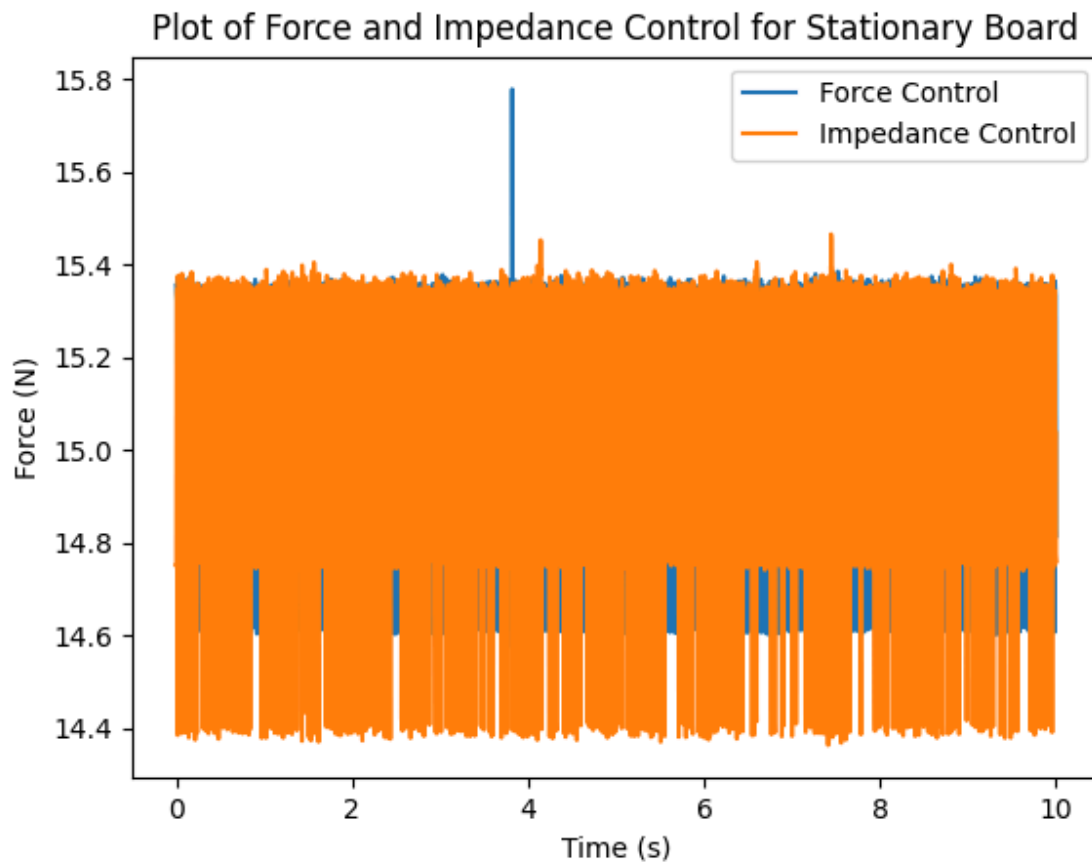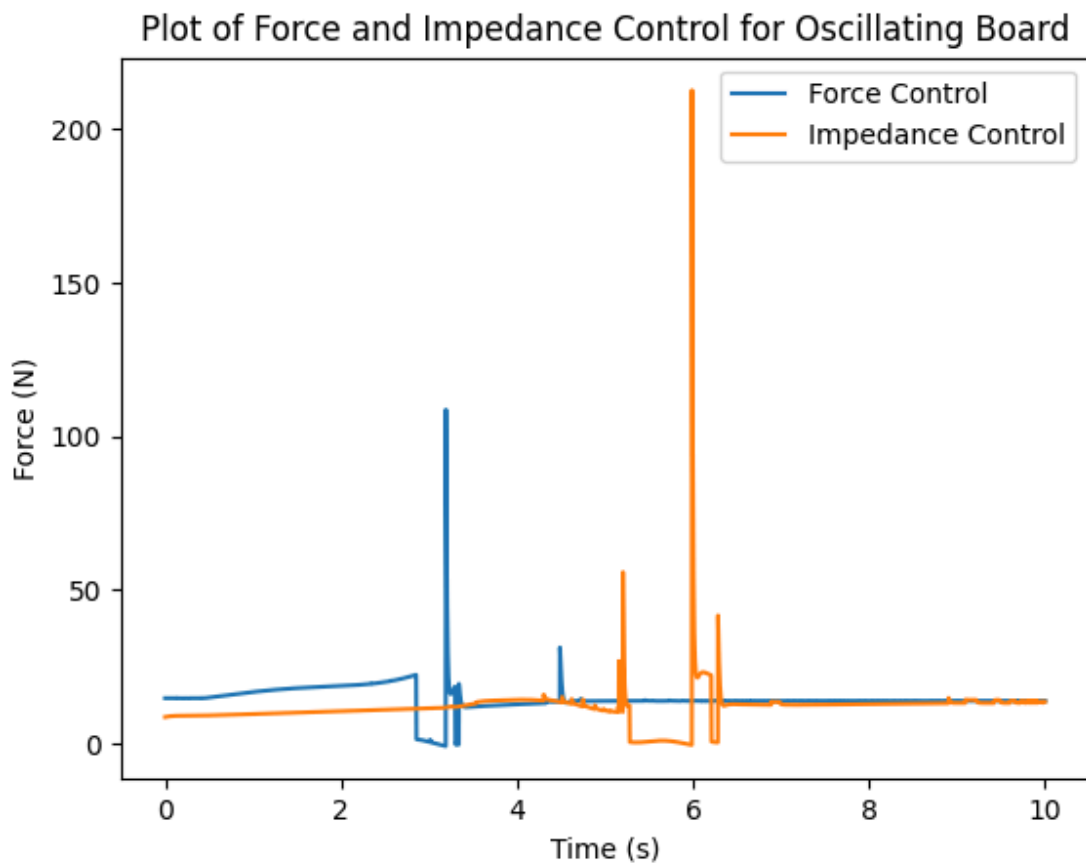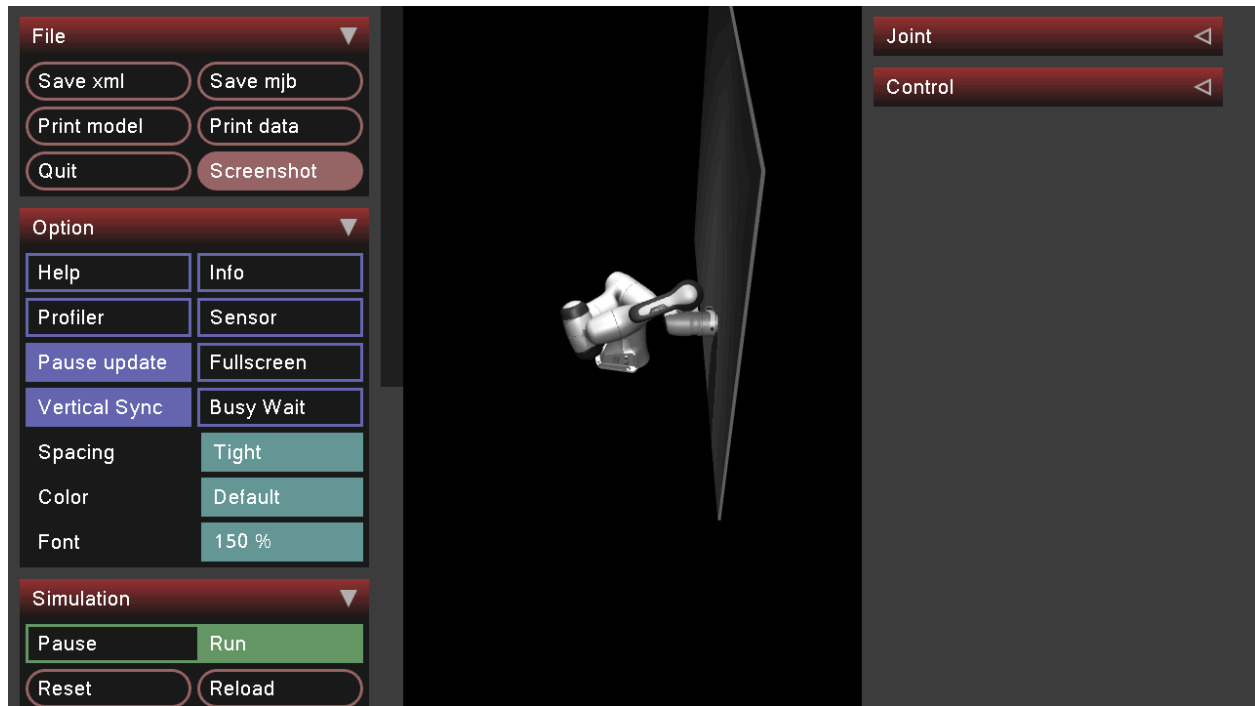## 3. PID Control

Plots for the impedance and force controls of the stationary and oscillating whiteboard scenarios are below.

Plot of Force and Impedance Control for Stationary Board

Plot of Force and Impedance Control for Oscillating Board

Below is a screenshot of when the oscillating whiteboard is closest to the robot's base.

Explanation of Differences between controllers:

Force controllers try to apply a specific force at the end effector independent of the interaction on the robot, which can lead to non-adaptive behavior; whereas, impedance controllers alter the robot's force response based on the forces that it encounters, which allows this method to be more adaptable to external forces. This can be seen in the results in how with the stationary whiteboard, the impedance one varies more since it is always trying to slightly adapt to its interactions rather than just apply a constant force. This can also be seen in the oscillating whiteboard plots in how the impedance controller is varying much more in the amount of force it is applying.

4. Kinematics for Franka

The outputs for Q1, Q2, and Q3 are below along with the final joint angles for the end effector pose for the IK solution. These values were taken directly from the printed output.

Q1:
Joints:
[0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
computed FK ee position
[8.80000000e-02 -8.93992163e-18 9.26000000e-01]
computed FK ee rotation
[[1.0000000e+00 0.0000000e+00 0.0000000e+00]
 [0.0000000e+00 -1.0000000e+00 -1.2246468e-16]
 [0.0000000e+00 1.2246468e-16 -1.0000000e+00]]

Q2:
Joints:
[0, 0, -0.7853981633974483, -0.2617993877991494, 0.3490658503988659, 0.2617993877991494, -1.3089969389957472]
computed FK ee position
[0.15710277 -0.10259332 0.93602711]
computed FK ee rotation
[[0.64935398 0.75871099 0.05193309]
 [0.7552124 -0.65137389 0.07325497]
 [0.08940721 -0.00834789 -0.99596017]]

Q3:
Joints:
[0, 0, 0.5235987755982988, -1.0471975511965976, -1.1344640137963142, 0.7853981633974483, 0.0]
computed FK ee position
[0.40136375 0.08742801 0.85526363]
computed FK ee rotation
[[0.98015816 -0.18113365 -0.08050201]
 [-0.17410263 -0.5925751 -0.78647507]
 [0.09475362 0.78488557 -0.61235316]]

Inverse Kinematic Values:
Error 4.248946814265874e-07 0.00021552899481566316
Computed IK angles [0.5739135882434608, 0.3115768395358409, -0.6794929683596144, -2.078769839249494, -0.11509029184146788, 3.914148734976127, -2.864391871800463]

A screenshot for the position of the robot for the inverse kinematic solution is below.