## Instructions to run:

To run the Simulink files for cases 0 and 1, you must change the case_num constant block value in the Simulink graphical programming environment. Case 0 will give the output for the case $q_d$ = [π/3, π/4], and case 1 will give the output for the case $q_d$ = [π/4 sin(t), π/5 cos(t)].

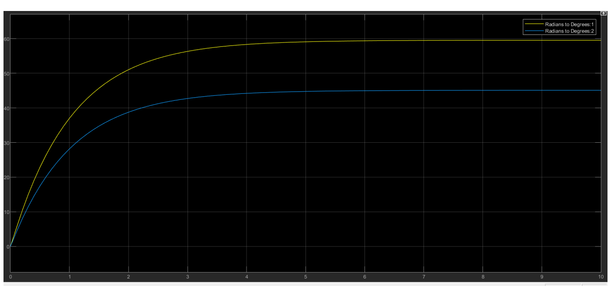
After this, you would need to plot the values for the arms of the robot using the Corke toolbox. The script for this is in demo.m. After running the file, the frames for the motion of the robot with the applied torque can be observed in the case_0/ or case_1/ directories, depending on the experiment.

These frames have been compiled into a mp4 video using the ffmpeg tool. The outputs are both available in the case_0.mp4 and case_1.mp4 files. The command is: ffmpeg -framerate 10.1 -i case_0/%04d.png -vf "scale=876:656" -c:v libx264 -pix_fmt yuv420p case_0/output_video.mp4.

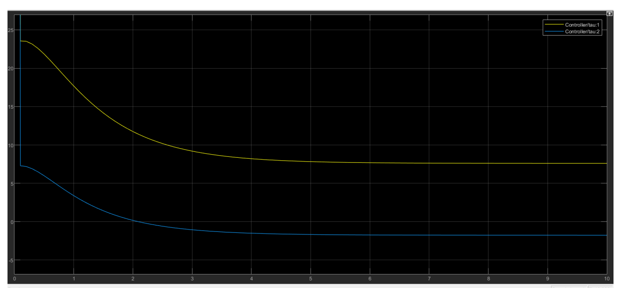
The baseline code for this has been uploaded in the classroom. I have modified the same code with the conditions provided.

## Plots:

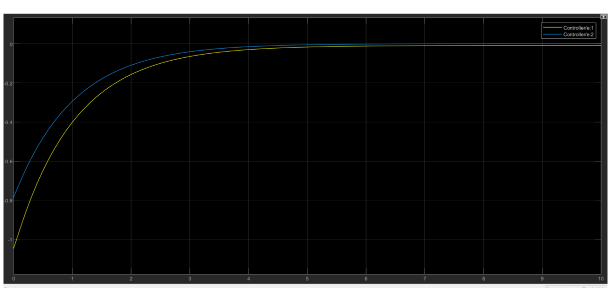
**Case 0:**



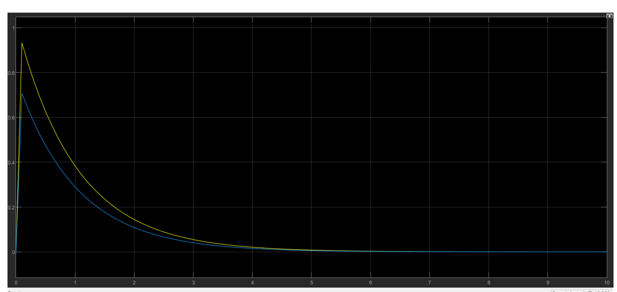
theta v/s t



tau v/s t

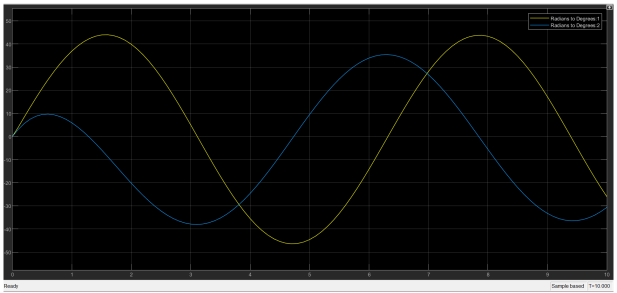


e v/s t

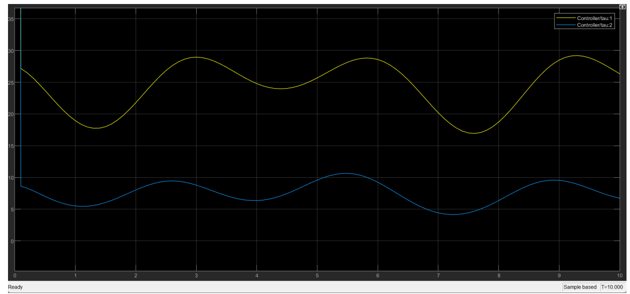


e_dot v/s t

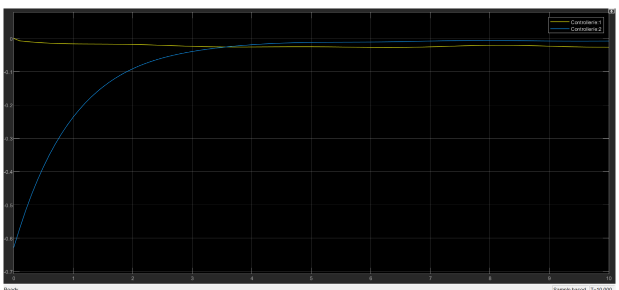
**Case 1:**



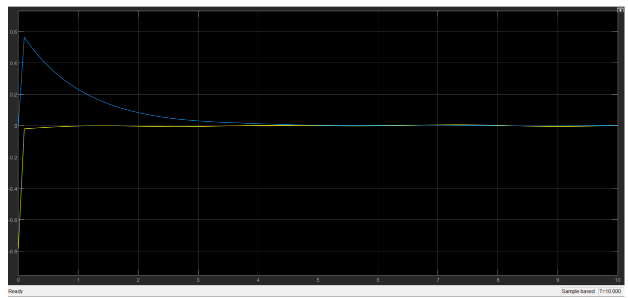
theta v/s t



tau v/s t



e v/s t



e_dot v/s t

## Plot Explanations:

**Case 0:**

theta v/s t: We can observe that the graph is saturating at the provided values of 60 degrees and 45 degrees.

tau v/s t: Initially, the torque applied is very high since the difference between the required angles and the actual angles is very high. As the angles begin to get closer to the required values, the torque abates and saturates. In the case of the first arm (yellow), the torque has a positive value to sustain against gravity; however, in the case of the other arm (blue), the value of the torque is negative, indicating that the rotor is applying force in the opposite direction. This is because 60+45 = 105 degrees, which would oblique the second arm to an angle more than 90 degrees, requiring a negative torque to sustain.

e v/s t: The value of the error is initially high due to the massive gap between the required angle and the current angle. As this gap abates, the value of the error saturates to 0.

e_dot v/s t: The value of the e_dot parameter can be thought of as the velocity parameter in the case of a fixed required angle. As the initial velocity would be high, given the gap between the required and current angles, the e_dot value would also be high. But once this gap abates, the e_dot value subsides.

**Case 1:**

theta v/s t: In this graph, we can see the shift in the paradigm as compared to the previous case. As the required angle varies with time, there is no saturation present in the angles, and they are constantly changing.

tau v/s t: As there is a significant difference in the initial values of required and current values of the angles, the force required to move the robot arms is significant. However, as some time passes, the force required is not that significant. This is because the shift in the model's required angle is gradual and not sudden. Thus, the changes in the torque provided for the arms are also not as sudden. A point to be noted is that the values of these torques are always greater than 0, unlike the other case, since gravity is doing its job of bringing the arms down whenever required. Thus, there is no need to apply significant force against gravity to achieve the desired clockwise motion.

e v/s t: The value for error is none in the first arm when the motion starts and a lot for the second arm. The reason for this is the sine term with the first arm, causing the initial angle of the first arm to be 0. The errors of the arms kind of saturate close to 0 after some time; however, it can be observed that these values are never exactly 0. The reason for this is that the required angle constantly changes, and by the time the current angle achieves its desired location, the required angle changes more.

e_dot v/s t: This value can also be thought of as the velocity of the error term. Since the errors at the beginning are significant, the graph assumes higher values. But as time progresses, the values of the errors cease, causing the velocity of the error also to reduce. However, like in the case of the error parameter, we can see that the velocity of the error never saturates but oscillates around the value of 0.