Here we are simulating control of the robot shown above. We have already obtained the dynamics of this robot in the dynamics section. The robot starts at joint position $\theta = 0$. Here $L = 1$, $m_1 = m_2 = m_3 = 1$, and $I_3 = 0.1$.

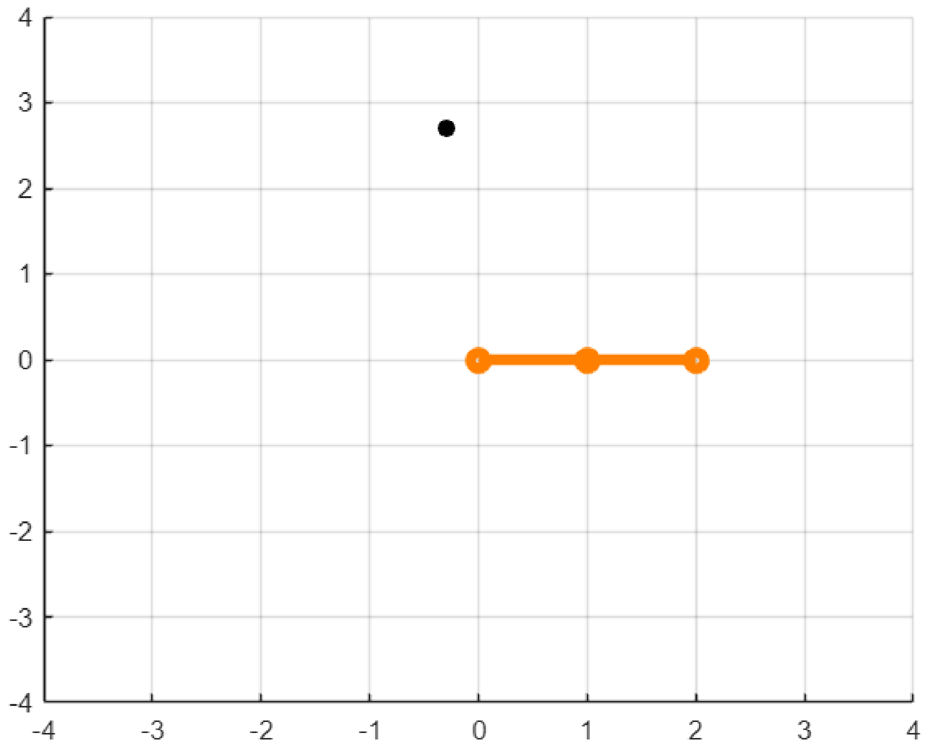
We will modify the code as needed so that the robot reaches for θ_d using multivariable PD control with gravity compensation:

$$\tau = \mathrm{K} * \mathrm{P}(\theta_d - \theta) - \mathrm{K} * D * \dot{\theta} + g(\theta)$$

CASE 1: A simulation where $\mathrm{K}_p = I$ and $\mathrm{K}_d = I$. Let the desired position be: $\theta_d = \begin{bmatrix} -2 \\ 2 \\ \frac{\pi}{4} \end{bmatrix}$

```
close all
clear
clc

% create figure
figure
axis([-4, 4, -4, 4])
grid on
hold on

% save as a video file
v = VideoWriter('Case_1.mp4', 'MPEG-4');
v.FrameRate = 100;
open(v);

% pick your system parameters
m1 = 1;
m2 = 1;
m3 = 1;
I3 = 0.1;
L = 1;
g = 9.81;
deltaT = 0.01;

% initial conditions
theta = [0; 0; 0];
thetadot = [0; 0; 0];
thetadotdot = [0; 0; 0];
time = 0;

% forward kinematics to end-effector
S1 = [0;0;0;1;0;0];
S2 = [0;0;0;0;1;0];
S3 = [0;0;1;0;-L;0];
S = [S1, S2, S3];
M3 = [eye(3), [2*L;0;0]; 0 0 0 1];
```

```
% For Case 1
Kp = eye(3);
Kd = eye(3);

M0 = [eye(3), [L;0;0]; 0 0 0 1];
M1 = [eye(3), [L;0;0]; 0 0 0 1];
M2 = [eye(3), [L;0;0]; 0 0 0 1];

for idx = 1:1000

    % get desired position
    theta_d = [-2; 2; pi/4];
    thetadot_d = [0; 0; 0];
    T_d = fk(M3, [S1 S2 S3], theta_d);

    % plot the robot
    p0 = [0; 0];
    T1 = fk(M1, S1,theta(1:1,:));
    p1 = T1(1:2,4);                         % position of end of link 1
    T2 = fk(M2,[S1 S2],theta(1:2,:));
    p2 = T2(1:2,4);                         % position of end of link 2
    T3 = fk(M3,[S1 S2 S3],theta(1:3,:));
    p3 = T3(1:2,4);                         % position of end of link 3
    P = [p0, p1, p2, p3];
    cla;
    plot(P(1,:), P(2,:), 'o-', 'color',[1, 0.5, 0],'linewidth',4)

    % plot the desired position
    plot(T_d(1,4), T_d(2,4), 'ok', 'MarkerFaceColor','k')
    drawnow
    frame = getframe(gcf);
    writeVideo(v,frame);

    % Mass matrix
    M = [m1 + m2 + m3, 0, -L*m3*sin(theta(3));
            0, m2 + m3, L*m3*cos(theta(3));
            -L*m3*sin(theta(3)), L*m3*cos(theta(3)), m3*L^2 + I3];

    % Coriolis matrix
    C = [0, 0, -L*thetadot(3)*m3*cos(theta(3));
        0, 0, -L*thetadot(3)*m3*sin(theta(3));
        0, 0,                 0];

    % Gravity vector
    G = [0; g*m2 + g*m3; L*g*m3*cos(theta(3))];

    % Reference from a journal and a book Modern Robotics (Just for reference and
knowledge)
    e1 =    theta_d - theta;
    e1dot = thetadot_d - thetadot;

    % Choose your controller tau
    tau = Kp*(theta_d-theta) + Kd*(thetadot_d - thetadot) + G;

    % integrate to update velocity and position
    thetadotdot = M \ (tau - C*thetadot - G);
    thetadot = thetadot + deltaT * thetadotdot;
    theta = theta + deltaT * thetadot;
    time = time + deltaT;

end
```



```
Warning: The video's width and height has been padded to be a multiple of two as required by the H.264 codec.
```

```
close(v);
close all
```