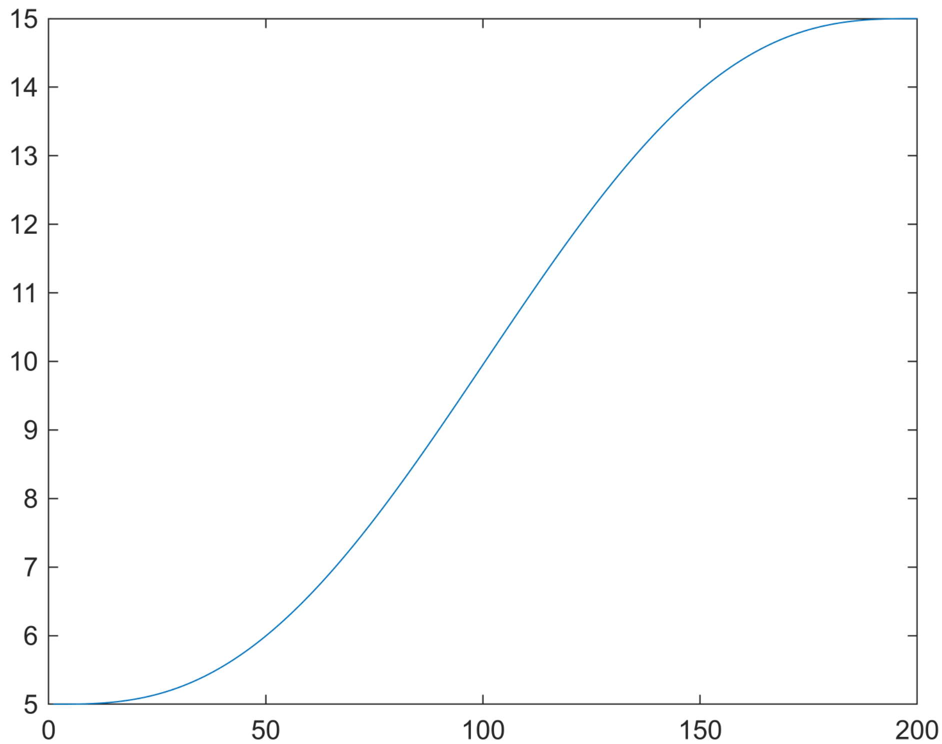
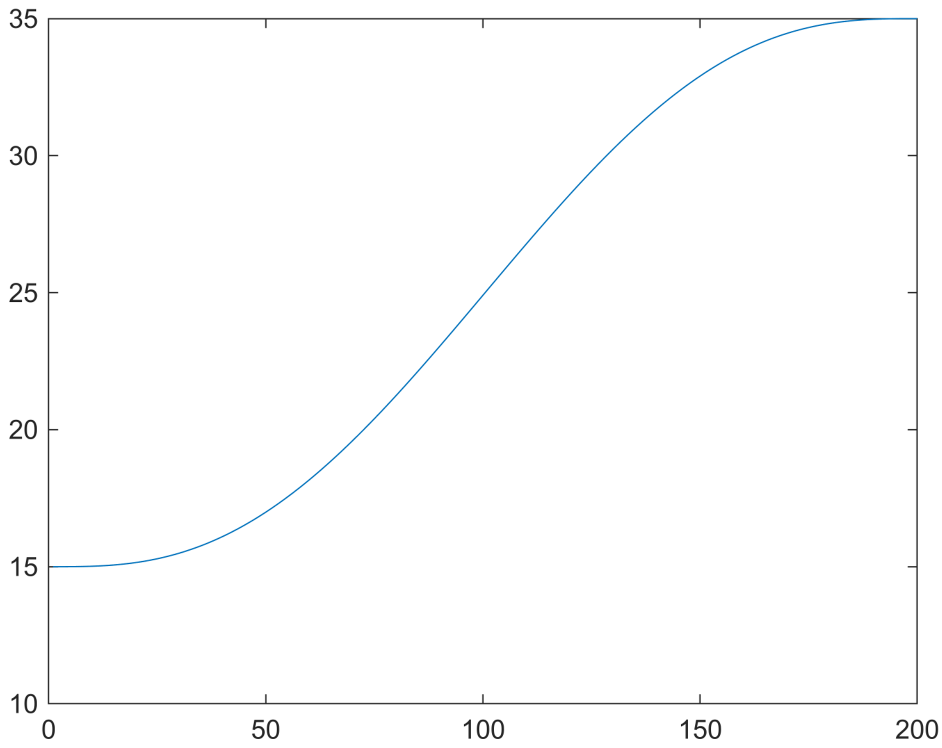
Q1

```
% first segment of the line from time 0 to 2 seconds
d = [5 0 0 15 0 0 0 2];

% coefficients of quintic polynomial trajectory
% q0 - initial position
% v0 - initial velocity
% ac0 - initial acceleration
% ql = final position
% v1- final velocity
% ac1 - final acceleration
% t_0 - initial time
% t_f - final time

q0 = d(1); v0= d (2); ac0 = d(3);
q1 = d(4); v1 = d(5); ac1 = d(6);
t_0 = d(7); t_f = d (8);

% creating a time vector to help in plotting
t = linspace (t_0, t_f, 100*(t_f-t_0));
c = ones (size (t));

% matrix of coefficients for the quintic polynomial
N =   [1  t_0   (t_0)^2   (t_0)^3      (t_0)^4      (t_0)^5;
       0   1     2*t_0    3*(t_0)^2   4*(t_0)^3    5*(t_0)^4;
       0   0       2        6*t_0     12*(t_0)^2   20*(t_0)^3;
       1  t_f   (t_f)^2   (t_f)^3      (t_f)^4      (t_f)^5;
       0   1     2*t_f    3*(t_f)^2   4*(t_f)^3    5*(t_f)^4;
       0   0       2        6*t_f     12*(t_f)^2   20*(t_f)^3];

% vector of the constants
b=[q0; v0; ac0; q1; v1; ac1];

% taking the inverse and multiplying to get the coefficients
a = inv(N) *b;

% Evaluating the position, velocity, and acceleration of the trajectory
qd = a(1).*c + a(2).*t + a(3).*t.^2 + a(4).*t.^3 + a(5).*t.^4 + a(6).*t.^5;
vd = a(2).*c + 2*a(3).*t + 3*a(4).*t.^2 + 4*a(5).*t.^3 + 5*a(6).*t.^4;
ad = 2*a(3).*c + 6*a(4).*t + 12*a(5).*t.^2 + 20*a(6).*t.^3;

plot(qd)
```



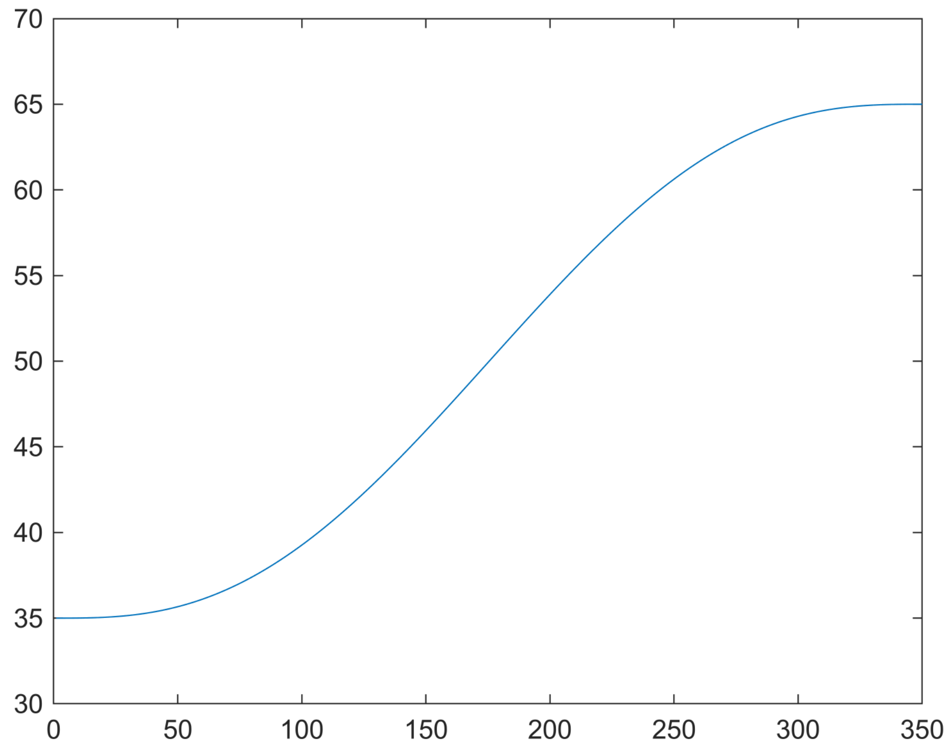

```
% Repeating the same steps for second segment for time 2 to 4 seconds
d = [15 0 0 35 0 0 2 4];
q0 = d(1); v0= d (2); ac0 = d(3);
q1 = d(4); v1 = d(5); ac1 = d(6);
t_0 = d(7); t_f = d (8);

t = linspace (t_0, t_f, 100*(t_f-t_0));
c = ones (size (t));

N = [1  t_0   (t_0)^2   (t_0)^3      (t_0)^4      (t_0)^5;
       0   1     2*t_0    3*(t_0)^2   4*(t_0)^3    5*(t_0)^4;
       0   0       2        6*t_0     12*(t_0)^2   20*(t_0)^3;
       1  t_f   (t_f)^2   (t_f)^3      (t_f)^4      (t_f)^5;
       0   1     2*t_f    3*(t_f)^2   4*(t_f)^3    5*(t_f)^4;
       0   0       2        6*t_f     12*(t_f)^2   20*(t_f)^3];

b=[q0; v0; ac0; q1; v1; ac1];
a = inv(N) *b;


qd1 = a(1).*c + a(2).*t + a(3).*t.^2 + a(4).*t.^3 + a(5).*t.^4 + a(6).*t.^5;
vd1 = a(2).*c + 2*a(3).*t + 3*a(4).*t.^2 + 4*a(5).*t.^3 + 5*a(6).*t.^4;
ad1 = 2*a(3).*c + 6*a(4).*t + 12*a(5).*t.^2 + 20*a(6).*t.^3;
```

```
plot(qd1)
```



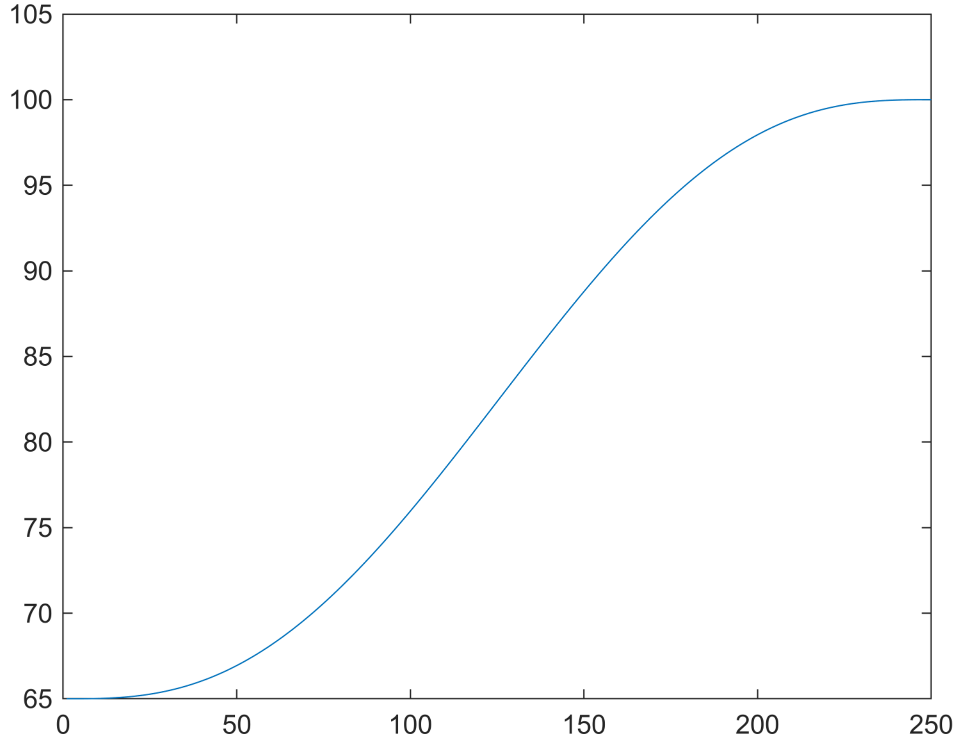

```
% Repeating the same steps for third segment for time 4 to 7.5 seconds
d = [35 0 0 65 0 0 4 7.5];
q0 = d(1); v0= d (2); ac0 = d(3);
q1 = d(4); v1 = d(5); ac1 = d(6);
t_0 = d(7); t_f = d (8);

t = linspace (t_0, t_f, 100*(t_f-t_0));
c = ones (size (t));

N = [1  t_0   (t_0)^2   (t_0)^3      (t_0)^4      (t_0)^5;
       0   1      2*t_0     3*(t_0)^2   4*(t_0)^3    5*(t_0)^4;
       0   0        2         6*t_0     12*(t_0)^2   20*(t_0)^3;
       1  t_f   (t_f)^2   (t_f)^3      (t_f)^4      (t_f)^5;
       0   1      2*t_f     3*(t_f)^2   4*(t_f)^3    5*(t_f)^4;
       0   0        2         6*t_f     12*(t_f)^2   20*(t_f)^3];

b=[q0; v0; ac0; q1; v1; ac1];
a = inv(N) *b;

qd2 = a(1).*c + a(2).*t + a(3).*t.^2 + a(4).*t.^3 + a(5).*t.^4 + a(6).*t.^5;
vd2 = a(2).*c + 2*a(3).*t + 3*a(4).*t.^2 + 4*a(5).*t.^3 + 5*a(6).*t.^4;
ad2 = 2*a(3).*c + 6*a(4).*t + 12*a(5).*t.^2 + 20*a(6).*t.^3;
```

```
plot(qd2)
```

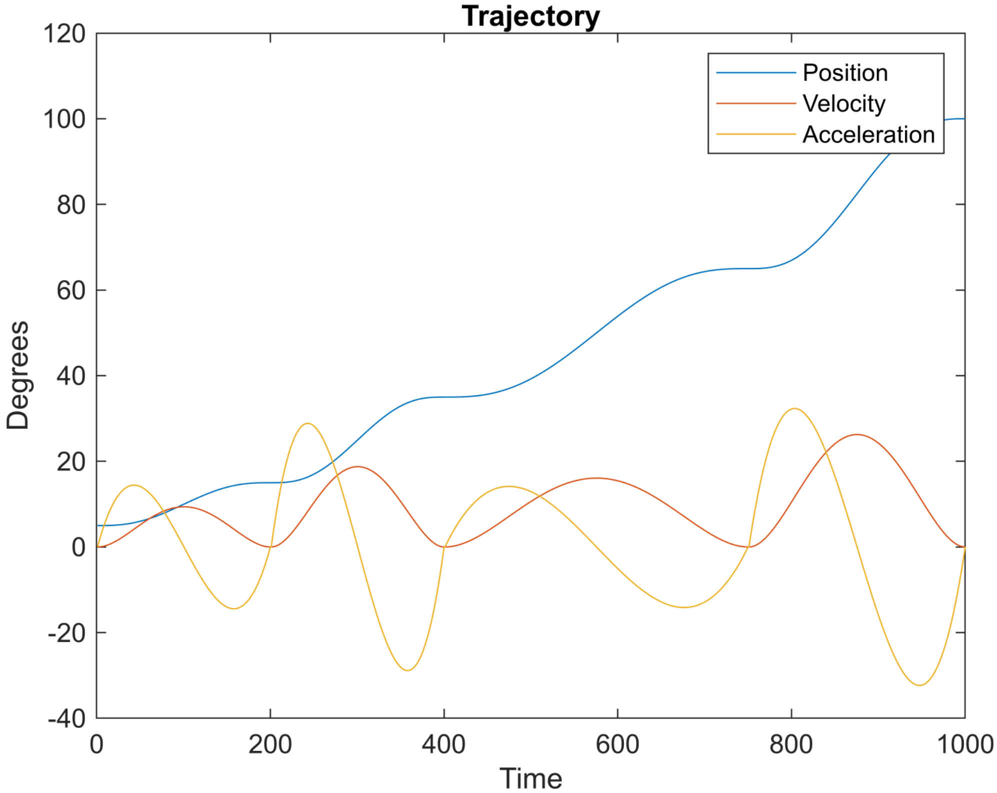



```
% Repeating the same steps for fourth segment for time 7.5 to 10 seconds
d = [65 0 0 100 0 0 7.5 10];
q0 = d(1); v0= d (2); ac0 = d(3);
q1 = d(4); v1 = d(5); ac1 = d(6);
t_0 = d(7); t_f = d (8);

t = linspace (t_0, t_f, 100*(t_f-t_0));
c = ones (size (t));

N = [1  t_0   (t_0)^2   (t_0)^3      (t_0)^4      (t_0)^5;
       0   1     2*t_0    3*(t_0)^2   4*(t_0)^3    5*(t_0)^4;
       0   0       2        6*t_0     12*(t_0)^2   20*(t_0)^3;
       1  t_f   (t_f)^2   (t_f)^3      (t_f)^4      (t_f)^5;
       0   1     2*t_f    3*(t_f)^2   4*(t_f)^3    5*(t_f)^4;
       0   0       2        6*t_f     12*(t_f)^2   20*(t_f)^3];

b=[q0; v0; ac0; q1; v1; ac1];
a = inv(N) *b;


qd3 = a(1).*c + a(2).*t + a(3).*t.^2 + a(4).*t.^3 + a(5).*t.^4 + a(6).*t.^5;
vd3 = a(2).*c + 2*a(3).*t + 3*a(4).*t.^2 + 4*a(5).*t.^3 + 5*a(6).*t.^4;
ad3 = 2*a(3).*c + 6*a(4).*t + 12*a(5).*t.^2 + 20*a(6).*t.^3;
```

```
plot(qd3)
```

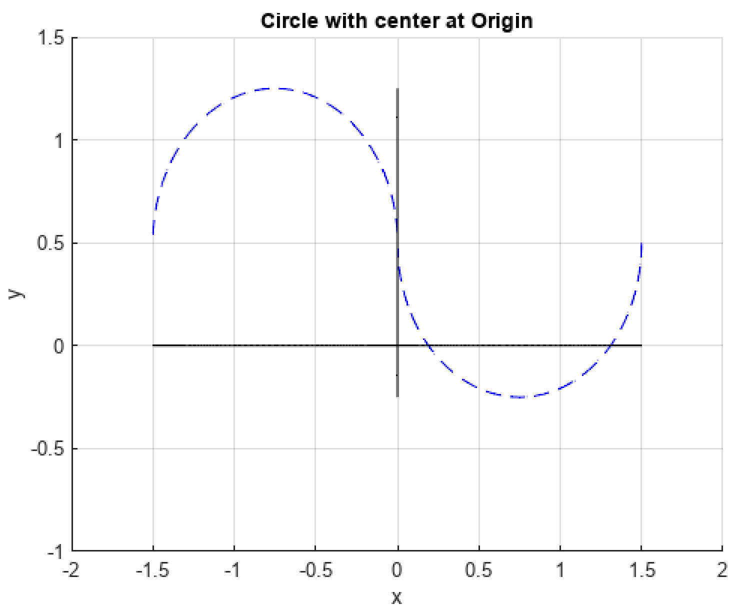



```
% qd position trajectory
% vd - velocity trajectory
% ad - acceleration trajectory

% joining all the different segments together to get the trajectory
qd = [qd qd1 qd2 qd3];
vd = [vd vd1 vd2 vd3];
ad = [ad ad1 ad2 ad3];
plot(qd)
hold on
plot(vd)
hold on
plot(ad)
xlabel("Time")
ylabel("Degrees")
title("Trajectory")
legend(["Position", "Velocity", "Acceleration"])
```



Here we get the trajectory along with velocity and acceleration. The x-axis is is multiplied by 100 so sactually this time is 0 to 10s.

```
Q2 % PART A
Given_Radius = 0.75; % Radius of the circle
POINTS = [1.5 0.5]; % Position of point P

AngR_1 = 0:1/100:pi;
AngR_2 = pi:1/100:2*pi;

angleRange = [AngR_1 AngR_2];

XCord = Given_Radius*cos(AngR_1) + Given_Radius;
XCord_2 = -Given_Radius*cos(AngR_2) - Given_Radius;

XCORDINATES = [XCord XCord_2];
YCord = -Given_Radius*sin(angleRange) + POINTS(2);

figure;
hold on
plot(XCORDINATES, YCord, '--b',"LineWidth",0.3);

plot(XCORDINATES, zeros(length(XCORDINATES)),"k","LineWidth",0.5)
plot(zeros(length(YCord)), YCord,"k","LineWidth",0.5)

xlim([-2,2])
ylim([-1,1.5])
grid on

title('Circle with center at Origin')
xlabel('x')
ylabel('y')
```

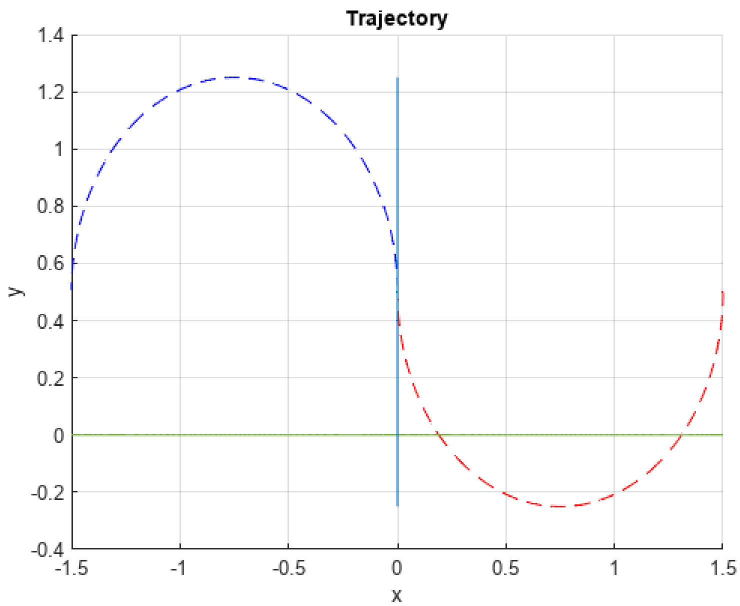



```
TR1 = 0:1/100:pi*Given_Radius;
TR2 = pi*Given_Radius:1/100:2*pi*Given_Radius;

SR1 = (TR1/Given_Radius);
SR2 = (TR2/Given_Radius);
t = [TR1 TR2];
y1 = -Given_Radius*sin(SR1) + 0.5;
x1 = Given_Radius*cos(SR1) + Given_Radius;
x2 = -Given_Radius*cos(SR2) - Given_Radius;
y2 = Given_Radius*sin(SR1) + 0.5;
XCORDINATES = [x1 x2];
YCord = [y1 y2]
```

```
YCord = 1×472
    0.5000    0.4900    0.4800    0.4700    0.4600    0.4500    0.4401 ⋯
```

```
% Create a figure window and plot the trajectory
figure;
hold on
plot(x1, y1, '--r');
plot(x2, y2, '--b');

plot([x1 x2], zeros(length([x1 x2])))
plot(zeros(length([y1 y2])), [y1 y2])

grid on
title('Trajectory')
xlabel('x')
```

```
ylabel('y')
```




```
%% PART B
Dist_P = 2*pi*Given_Radius;
velocity = 1;
time = vpa(Dist_P/velocity,8)
```

time =
4.712389

```
%% PART C
% Define the lengths of the two links
L1 = 1;
L2 = 1;
% Calculate the Beta
B_numerator = L1^2 + L2^2 - XCORDINATES.^2 - YCord.^2;
B_Denomenator = 2 * L1 * L2;
beta = B_numerator / B_Denomenator;
% Calculate the alpha
A_numerator = L1^2 + XCORDINATES.^2 + YCord.^2 - L2.^2;
A_Denumerator = 2 * L1 * sqrt(XCORDINATES.^2 + YCord.^2);
alpha = A_numerator / A_Denumerator
```

alpha = 0.6996

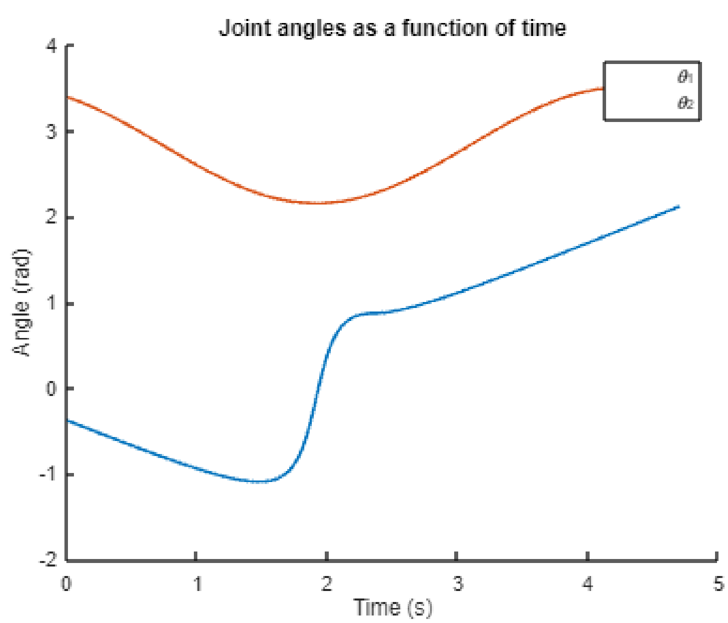
```
% Calculate the gamma
gamma = atan2(YCord, XCORDINATES)
```

gamma = 1×472
0.3218 0.3158 0.3098 0.3038 0.2978 0.2918 0.2858 ⋯

```
% Calculate theta2 and theta1 (joint angles)
theta2 = pi - beta;
theta1 = gamma - alpha
```

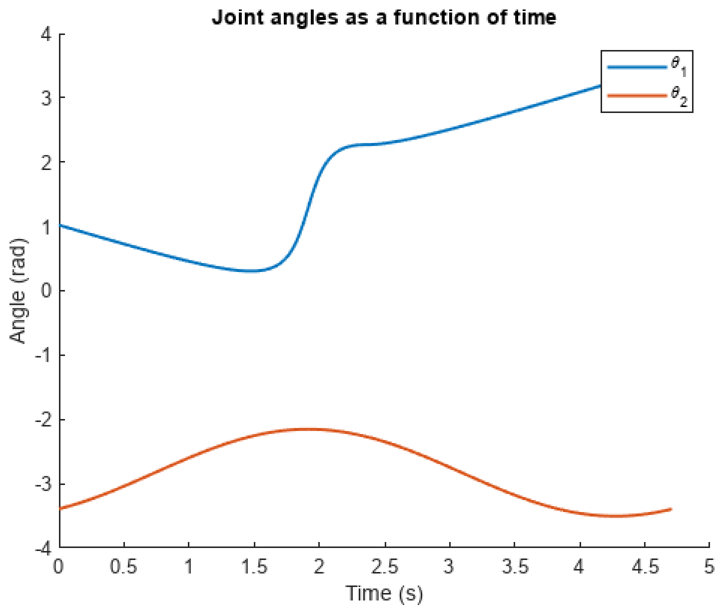
```
theta1 = 1×472
   -0.3778   -0.3838   -0.3898   -0.3958   -0.4018   -0.4078   -0.4138 ⋯
```

```
% Create a new figure window and plot theta1 and theta2
figure;
hold on
plot(t, theta1, 'LineWidth', 1.5)
plot(t, theta2, 'LineWidth', 1.5)
% Add labels to the plot
title('Joint angles as a function of time')
xlabel('Time (s)')
ylabel('Angle (rad)')
legend('\theta_1', '\theta_2')
```




```
% Recalculate theta2 and theta1 with a different sign
theta2 = -pi + beta;
theta1 = gamma + alpha;
% Create a new figure window and plot theta1 and theta2
figure;
hold on
plot(t, theta1, 'LineWidth', 1.5)
plot(t, theta2, 'LineWidth', 1.5)

title('Joint angles as a function of time')
xlabel('Time (s)')
```

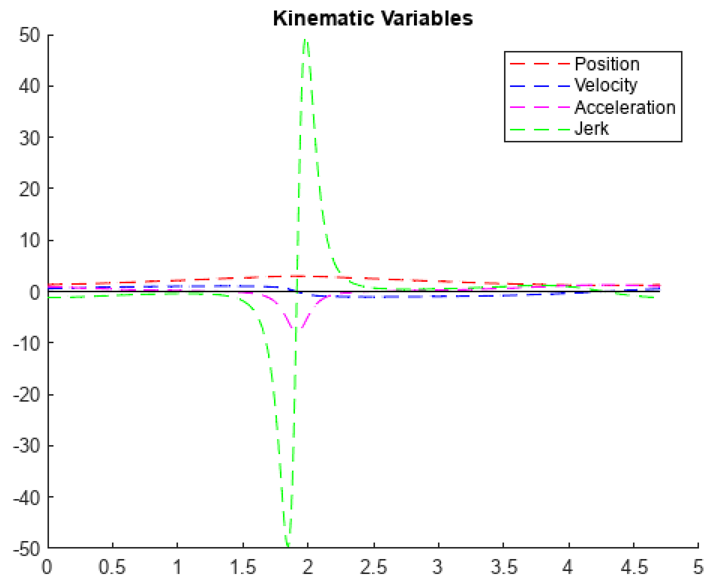
```
ylabel('Angle (rad)')
legend('\theta_1', '\theta_2')
```



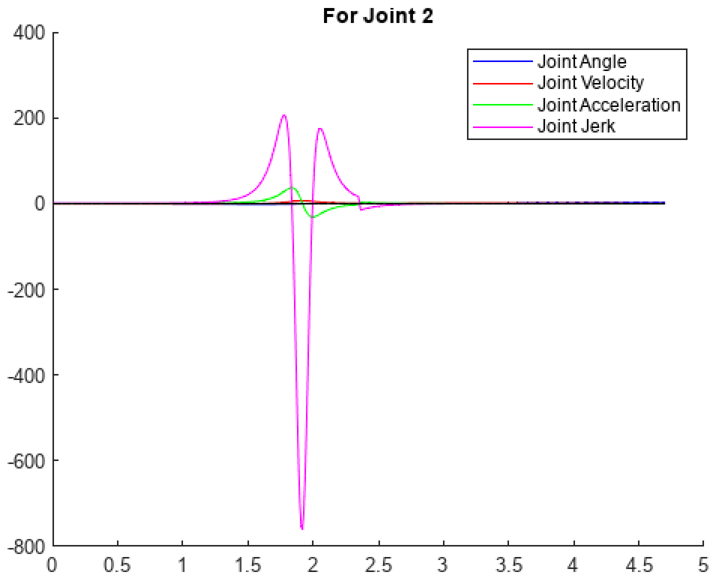

```
% SETTING SYSTEM VARIABLES AND EQUATIONS
syms x_val y_val t s_val
L1 = 1;
L2 = 1;
B_numerator1_val = L1^2+L2^2 -x_val.^2 -y_val.^2;
B_Denomenator1_val = 2*L1*L2;
B_Value = acos(B_numerator1_val/B_Denomenator1_val);
A_numerator1_val = L1^2+x_val.^2+y_val.^2-L2.^2;
A_Denumerator1_val = 2*L1*((x_val.^2+y_val.^2).^(1/2));
alpha_val = acos(A_numerator1_val ./ A_Denumerator1_val);
gamma_val = atan2(y_val, x_val);
theta1_val = simplify(pi - B_Value);
theta2_val = simplify(gamma_val - alpha_val);
s_val = t/Given_Radius;
theta1_val = subs(theta1_val, y_val, -Given_Radius*sin(s_val) + POINTS(2));
theta2_val = subs(theta2_val, y_val, -Given_Radius*sin(s_val) + POINTS(2));
Theta1 = subs(theta1_val, x_val, Given_Radius*cos(s_val) + Given_Radius);
Theta2 = subs(theta2_val, x_val, Given_Radius*cos(s_val) + Given_Radius);
T1_initial = subs(theta1_val, x_val, -Given_Radius*cos(s_val) - Given_Radius);
T2_initial = subs(theta2_val, x_val, -Given_Radius*cos(s_val) - Given_Radius);
w1_End_Val = diff(Theta1, t);
w1_initial = diff(T1_initial, t);
a1_End_Val = diff(w1_End_Val, t);
```

```
a1_initial = diff(w1_initial, t);
j1_End_Val = diff(a1_End_Val, t);
j1_initial = diff(a1_initial, t);
w2_End_Val = diff(Theta2, t);
w2_initial = diff(T2_initial, t);
a2_End_Val = diff(w2_End_Val, t);
a2_initial = diff(w2_initial, t);
j2_End_Val = diff(a2_End_Val, t);
j2_initial = diff(a2_initial, t);
t_1 = 0:1/100:pi*Given_Radius;
t2 = pi*Given_Radius + 1/100:1/100:2*pi*Given_Radius;
Theta1 = subs(Theta1, t, t_1);
T1_initial = subs(T1_initial, t, t2);
w1_End_Val = subs(w1_End_Val, t, t_1);
w1_initial = subs(w1_initial, t, t2);
a1_End_Val = subs(a1_End_Val, t, t_1);
a1_initial = subs(a1_initial, t, t2);
j1_End_Val = subs(j1_End_Val, t, t_1);
j1_initial = subs(j1_initial, t, t2);
Theta2 = subs(Theta2, t, t_1);
T2_initial = subs(T2_initial, t, t2);
w2_End_Val = subs(w2_End_Val, t, t_1);
w2_initial = subs(w2_initial, t, t2);
a2_End_Val = subs(a2_End_Val, t, t_1);
a2_initial = subs(a2_initial, t, t2);
j2_End_Val = subs(j2_End_Val, t, t_1);
j2_initial = subs(j2_initial, t, t2);
% Plotting
t = [t_1 t2];
theta_Sum = [Theta1 T1_initial];
w_Sum = [w1_End_Val w1_initial];
a_Sum = [a1_End_Val a1_initial];
j_Sum = [j1_End_Val j1_initial];
theta2_Sum = [Theta2 T2_initial];
w2_Sum = [w2_End_Val w2_initial];
a2_Sum = [a2_End_Val a2_initial];
j2_Sum = [j2_End_Val j2_initial];
figure;
hold on
title("Kinematic Variables");
plot(t, theta_Sum, '--r');
plot(t, w_Sum, '--b');
plot(t, a_Sum, '--m');
plot(t, j_Sum, '--g');
plot(t, zeros(length(t)), 'k');
```

```
legend(["Position", "Velocity", "Acceleration", "Jerk"]);
```




```
figure;
hold on
title("For Joint 2");
plot(t, theta2_Sum , 'b');
plot(t, w2_Sum , 'r');
plot(t, a2_Sum , 'g');
plot(t, j2_Sum , 'm');
plot(t, zeros(length(t)), 'k');
legend(["Joint Angle", "Joint Velocity", "Joint Acceleration", "Joint Jerk"]);
```




```
% PART D
[w_1_max_val, w1_pos] = max(w_Sum);
[w_2_max_val, w2_pos] = max(w2_Sum);
max_w1_val_and_q1_pos = simplify([w_1_max_val, theta_Sum(w1_pos)])
```

max_w1_val_and_q1_pos =

$$\left(\frac{16\left(\frac{\cos\left(\frac{134}{75}\right)}{2}+\frac{3\sin\left(\frac{134}{75}\right)}{4}\right)}{\sqrt{256-\left(6\sin\left(\frac{134}{75}\right)-9\cos\left(\frac{134}{75}\right)+5\right)^2}} \quad \pi-\mathrm{acos}\left(\frac{3\sin\left(\frac{134}{75}\right)}{8}-\frac{9\cos\left(\frac{134}{75}\right)}{16}+\frac{5}{16}\right)\right)$$

```
max_w2_val_and_q2_pos = simplify([w_2_max_val, theta2_Sum(w2_pos)])
```

max_w2_val_and_q2_pos =

$$\left(-\frac{6\cos\left(\frac{64}{25}\right)-4\sin\left(\frac{64}{25}\right)+6}{9\cos\left(\frac{64}{25}\right)-6\sin\left(\frac{64}{25}\right)+11}-\frac{4\sqrt{6}\left(\cos\left(\frac{64}{25}\right)+\frac{\sigma_3}{2}\right)}{3\sigma_1\sqrt{2\sin\left(\frac{64}{25}\right)-3\cos\left(\frac{64}{25}\right)+7}} \quad -\mathrm{atan}\left(\frac{\sigma_3-2}{3\sigma_2}\right)-\mathrm{acos}\left(\frac{\sigma_1}{8}\right)\right)$$

where

$$\sigma_1=\sqrt{9\sigma_2^2+(\sigma_3-2)^2}$$

$$\sigma_2=\cos\left(\frac{64}{25}\right)+1$$

$$\sigma_3=3\sin\left(\frac{64}{25}\right)$$

```
% PART E
[a1_max_val, a1_pos] = max(a_Sum);
[a2_max_val, a2_pos] = max(a2_Sum);
max_a1_val_and_q1_pos = simplify(expand([a1_max_val, theta_Sum(a1_pos)]))
```

max_a1_val_and_q1_pos =

$$\left(\frac{16\sqrt{6}\left(228\cos\left(\frac{4814566978148503}{844424930131968}\right)+25\cos\left(\frac{4814566978148503}{422212465065984}\right)-152\sin\left(\frac{4814566978148503}{844424930131968}\right)-60\sin\left(\frac{4814566978148503}{422212465065984}\right)+195\right)}{9\left(60\cos\left(\frac{4814566978148503}{844424930131968}\right)-15\cos\left(\frac{4814566978148503}{422212465065984}\right)-40\sin\left(\frac{4814566978148503}{844424930131968}\right)+36\sin\left(\frac{4814566978148503}{422212465065984}\right)+115\right)^{3/2}} \quad \pi-\operatorname{acos}\left(\frac{3\sin\left(\frac{4814566978148503}{844424930131968}\right)}{8}-\frac{9\cos\left(\frac{4814566978148503}{844424930131968}\right)}{16}+\frac{5}{16}\right)\right)$$

```
max_a2_val_and_q2_pos = simplify(expand([a2_max_val, theta2_Sum(a2_pos)]))
```

max_a2_val_and_q2_pos =

$$\left(-\frac{32\sqrt{3}\left(\frac{241785\cos\left(\frac{184}{15}\right)}{16}+\frac{2233413\cos\left(\frac{184}{25}\right)}{16}-\frac{22741983\cos\left(\frac{184}{75}\right)}{8}-\frac{1499775\cos\left(\frac{368}{75}\right)}{2}+\frac{896427\cos\left(\frac{736}{75}\right)}{8}+\frac{24705\sin\left(\frac{184}{15}\right)}{8}+\frac{5707611\sin\left(\frac{184}{25}\right)}{8}+\frac{7580661\sin\left(\frac{184}{75}\right)}{4}+1799730\sin\left(\frac{368}{75}\right)+112995\sin\left(\frac{736}{75}\right)+132\sqrt{3}\cos\left(\frac{184}{75}\right)\sigma_1\sigma_2^{3/2}+1 + 108\sqrt{3}\cos\left(\frac{368}{75}\right)\sigma_1\sigma_2^{3/2}+198\sqrt{3}\sin\left(\frac{184}{75}\right)\sigma_1\sigma_2^{3/2}+45\sqrt{3}\sin\left(\frac{368}{75}\right)\sigma_1\sigma_2^{3/2}-\frac{16400943}{8}\right)}{27\sigma_1\sigma_2^{3/2}\left(243\cos\left(\frac{184}{25}\right)-16227\cos\left(\frac{184}{75}\right)-2970\cos\left(\frac{368}{75}\right)+1242\sin\left(\frac{184}{25}\right)+10818\sin\left(\frac{184}{75}\right)+7128\sin\left(\frac{368}{75}\right)-13046\right)} \quad -\operatorname{atan}\left(\frac{3\sin\left(\frac{184}{75}\right)-2}{3\left(\cos\left(\frac{184}{75}\right)+1\right)}\right)-\operatorname{acos}\left(\frac{\sqrt{2}\sqrt{\sigma_2}}{8}\right)\right)$$

where

$$\sigma_1=\left(2\sin\left(\frac{184}{75}\right)-3\cos\left(\frac{184}{75}\right)+7\right)^{3/2}$$

$$\sigma_2=9\cos\left(\frac{184}{75}\right)-6\sin\left(\frac{184}{75}\right)+11$$

```
% PART F
[j1_max_val, j1_pos] = max(j_Sum);
[j2_max_val, j2_pos] = max(j2_Sum);
max_j1_val_and_q1_pos = simplify([j1_max_val, theta_Sum(j1_pos)])
```

max_j1_val_and_q1_pos =

$$\left(-\frac{32\sqrt{6}\left(44372\cos\left(\frac{66}{25}\right)+60600\cos\left(\frac{132}{25}\right)+23276\cos\left(\frac{198}{25}\right)+1800\cos\left(\frac{264}{25}\right)+66558\sin\left(\frac{66}{25}\right)+25250\sin\left(\frac{132}{25}\right)-4554\sin\left(\frac{198}{25}\right)-1785\sin\left(\frac{264}{25}\right)\right)}{27\left(60\cos\left(\frac{66}{25}\right)-15\cos\left(\frac{132}{25}\right)-40\sin\left(\frac{66}{25}\right)+36\sin\left(\frac{132}{25}\right)+115\right)^{5/2}} \quad \pi-\operatorname{acos}\left(\frac{3\sin\left(\frac{66}{25}\right)}{8}-\frac{9\cos\left(\frac{66}{25}\right)}{16}+\frac{5}{16}\right)\right)$$

```
max_j2_val_and_q2_pos = simplify([j2_max_val, theta2_Sum(j2_pos)])
```

max_j2_val_and_q2_pos =

max_j2_val_and_q2_pos =

$$\left(-\frac{128\sqrt{3}\left(\frac{284408901\cos\left(\frac{178}{75}\right)}{32}+\frac{11333506887\cos\left(\frac{178}{25}\right)}{32}+\frac{7121696589\cos\left(\frac{178}{75}\right)}{32}-\frac{10512909\cos\left(\frac{356}{25}\right)}{4}+\frac{1897206165\cos\left(\frac{356}{75}\right)}{4}+1135190070\cos\left(\frac{712}{75}\right)-\frac{11944665\cos\left(\frac{1246}{75}\right)}{32}-\frac{2783477277\sin\left(\frac{178}{75}\right)}{64}-\frac{4434850521\sin\left(\frac{178}{25}\right)}{64}+\frac{21365089767\sin\left(\frac{178}{75}\right)}{64}-\cdots\right.}{243\,\sigma_2\,\sigma_1\left(243\cos\left(\frac{178}{25}\right)-16227\cos\left(\frac{178}{75}\right)-2970\cos\left(\frac{356}{75}\right)+1242\sin\left(\frac{178}{25}\right)+1\cdots\right.}\right.$$

where

$$\frac{\left.-\frac{103351545\sin\left(\frac{356}{25}\right)}{16}+\frac{3162010275\sin\left(\frac{356}{75}\right)}{16}-\frac{450292311\sin\left(\frac{712}{75}\right)}{4}-\frac{16216605\sin\left(\frac{1246}{75}\right)}{64}+1053\sqrt{3}\,\sigma_2\sigma_1+594\sqrt{3}\cos\left(\frac{178}{75}\right)\sigma_2\sigma_1-135\sqrt{3}\cos\left(\frac{356}{75}\right)\sigma_2\sigma_1-396\sqrt{3}\sin\left(\frac{178}{75}\right)\sigma_2\sigma_1+324\sqrt{3}\sin\left(\frac{356}{75}\right)\sigma_2\sigma_1\right)}{\left.+10818\sin\left(\frac{178}{75}\right)+7128\sin\left(\frac{356}{75}\right)-13046\right)}\;-\operatorname{atan}\left(\frac{\sigma_3}{3\,\sigma_4}\right)-\operatorname{acos}\left(\frac{\sqrt{9\sigma_4^2+\sigma_3^2}}{8}\right)\right)$$

where

$$\sigma_1=\left(9\cos\left(\frac{178}{75}\right)-6\sin\left(\frac{178}{75}\right)+11\right)^{5/2}$$

$$\sigma_2=\left(2\sin\left(\frac{178}{75}\right)-3\cos\left(\frac{178}{75}\right)+7\right)^{5/2}$$

$$\sigma_3=3\sin\left(\frac{178}{75}\right)-2$$

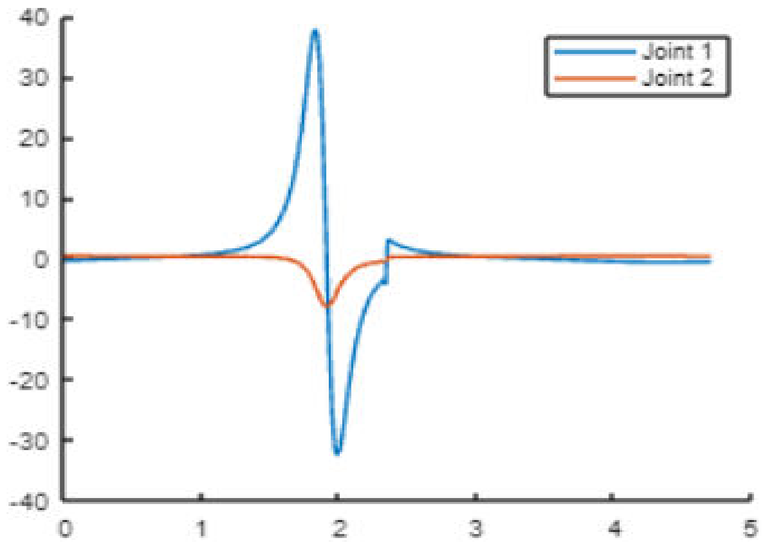
$$\sigma_4=\cos\left(\frac{178}{75}\right)+1$$

Q3 a

```
a1 = 1; a2 = 1;
ttheta1 = theta1.'
ttheta2 = theta2.'
dtheta22 = [dtheta2 dtheta2(471)].'
dtheta11 = [dtheta1 dtheta1(471)].'
ddtheta11 = [ddtheta1 ddtheta1(470) ddtheta1(470)].'
ddtheta22 = [ddtheta2 ddtheta2(470) ddtheta2(470)].'
global torque1;
torque1 = zeros(2,length(theta1))
for i=1:length(theta1)
      g1 = [(m1+m2)*a1*9.8*cos(theta1(i)) + m2*9.8*a2*cos(theta1(i) + 
  theta2(i)); m2*9.8*a2*cos(theta1(i) + theta2(i))];
      c = [-2*m2*a1*a2*sin(ttheta2(i)).*dtheta22(i) dtheta22(i); 
  m2*a1*a2*sin(ttheta2(i)).*dtheta11(i) zeros(size(dtheta22(i)))];
      jq = [m1*a1^2 + m2*(a1^2 + 2*a1*a2*cos(theta2(i)) + a2^2) 
  m2*(a1*a2*cos(theta2(i)) + a2^2);
           m2*(a1*a2*cos(theta2(i)) + a2^2) 
  m2*a2^2*ones(1,length(theta2(i)))];

  torque1(:,i) = jq*[ddtheta11(i);ddtheta22(i)] + c*[dtheta11(i);dtheta22(i)];

  end
torque1
figure;
hold on
plot(t, torque1(1,:))
plot(t, torque1(2,:))
```

```
legend(["Joint 1", "Joint 2"])
```

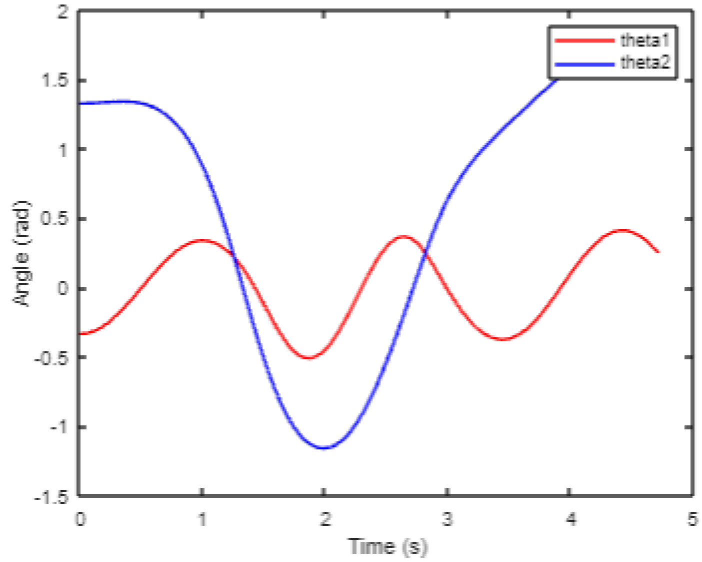
```
torque1 = 2×472
   -0.3800   -0.3718   -0.3635   -0.3552   -0.3469   -0.3386   -0.3303 ...
    0.3914    0.3902    0.3890    0.3878    0.3865    0.3853    0.3840
```



Q3b:

```
% Define system parameters
m1 = 1;  % mass of link 1
m2 = 1;  % mass of link 2
l1 = 1;  % length of link 1
l2 = 1;  % length of link 2
g = 9.81;  % gravitational constant
% Define the function that returns the derivative of the state vector
f = @(t, y, tau) [y(3); y(4); ...
    (tau + m2*l1*y(4)^2*sin(y(2)-y(1)) - (m1+m2)*g*sin(y(1))) / ...
    (m1*l1^2 + m2*l1^2*sin(y(2)-y(1))^2); ...
    (-tau - m2*l1*y(3)^2*sin(y(2)-y(1)) - m2*g*sin(y(2))*cos(y(2)-y(1))) /
...
    (m2*l2^2 + m2*l1^2*sin(y(2)-y(1))^2)]
% Set the initial conditions
theta1_0 = theta1(1);
theta2_0 = theta2(2);
dtheta1_0 = dtheta1(1);
dtheta2_0 = dtheta2(1);
y0 = [theta1_0; theta2_0; dtheta1_0; dtheta2_0];
% Set the time range and control torque
tspan = [0 2*pi*r];
tau = @(t) 0.1*sin(t);
% Solve the system of differential equations using ode45
[t, y] = ode45(@(t, y) f(t, y, tau(t)), tspan, y0);
```

```
% Plot the results
figure
plot(t, y(:, 1), 'r', t, y(:, 2), 'b')
xlabel('Time (s)')
ylabel('Angle (rad)')
legend('theta1', 'theta2')
```



The answer that I am getting is not correct but that is an issue with the differential equation.

Hussain: I spent 6 hour to complete this question in order to understand and implement the trajectory part I refered book chapter and slides

Rida: My part in this homework was to complete question 1 and 3.
I took almost 14 hours completing it but couldn't do so in the end as q3 required the theta values computed in q2 and I didn't have those. If we could just get q3b correct, q3 c and d could have been solved. This homework was really challenging and despite many people discussing the solution till late night, couldn't figure it out.