```
clear all
close all
clc

%%

c1 = 0.5;
l1 = 1;
I1 = 0.05;
m1 = 1;

c2 = 0.25;
l2 = 0.5;
I2 = 0.05;
m2 = 1;

g = 9.81;

param = [c1; l1; c2; l2; m1; I1; m2; I2; g];

p0 = [0, 0];

z = [pi/6; pi/6; 0; 0];
dim = length(z);
%num_step = 6000;
num_step = 10000
dt = 0.001;
energy_trj = [];

x0 = [0.5; -1];
radi = 0.3;
%omega = 2*pi*0.5;
omega = 3;

%restitution_coeff = 0.5;
restitution_coeff = 0;
% friction_coeff = 0.3;
friction_coeff = 3;
ground_height = -1.1;

tspan = zeros(1, num_step);
x_des_trj = zeros(dim/2, num_step);
dx_des_trj = zeros(dim/2, num_step);

x_trj = zeros(dim/2, num_step);
dx_trj = zeros(dim/2, num_step);

z_trj = zeros(dim, num_step);

```

```
 50 for i=1:num_step
 51     t = i*dt;
 52     tspan(i) = t;
 53 
 54    x_des = x0 + [radi*cos(omega*t); radi*sin(omega*t)];
 55    dx_des = [-radi*omega*sin(omega*t); radi*omega*cos(omega*t)];
 56    ddx_des = [-radi*omega^2*cos(omega*t); -radi*omega^2*sin(omega*t)];
 57 
 58    x_des_trj(:,i) = x_des;
 59    dx_des_trj(:,i) = dx_des;
 60 
 61    u = controller(z, param, x_des, dx_des, ddx_des);
 62    dz = dyn_pend(z, u, param);
 63 
 64 
 65    z(dim/2+1:end) = z(dim/2+1:end) + dz(dim/2+1:end) * dt;
 66    z(1:dim/2) = z(1:dim/2) + z(dim/2+1:end)*dt;
 67    % update function goes here
 68    z(3:4) = discrete_impact_contact(z, param, restitution_coeff, friction_coeff, ↙
ground_height);
 69 
 70    z_trj(:,i) = z;
 71 
 72    key_pt = keypoints_pend(z, param);
 73    rA = key_pt(:,1);
 74    rB = key_pt(:,2);
 75 
 76    x_trj(:,i) = rB;
 77    dx_trj(:,i) = velocity_foot(z, param);
 78 end
 79 
 80 
 81 figure
 82 subplot(2,1,1)
 83 plot(tspan, x_des_trj(1,:), tspan, x_trj(1,:));
 84 ylabel('x')
 85 subplot(2,1,2)
 86 plot(tspan, x_des_trj(2,:), tspan, x_trj(2,:));
 87 ylabel('y')
 88 
 89 figure
 90 subplot(2,1,1)
 91 plot(tspan, z_trj(1,:));
 92 ylabel('q1')
 93 subplot(2,1,2)
 94 plot(tspan, z_trj(2,:));
 95 ylabel('q2')
 96 
 97 %%
```

```
 98 figure
 99 % Prepare plot handles
100 hold on
101
102 % Target traj
103 TH = 0:.1:2*pi;
104 plot( x0(1) + radi * cos(TH), ...
105       x0(2) + radi * sin(TH),'k--');
106 % plot(x0(1), x0(2),'*')
107 h_OA = plot([0],[0],'LineWidth',4);
108 h_AB = plot([0],[0],'LineWidth',4);
109
110 % Ground Q2.3
111 plot([-1.5 1.5],[ground_height ground_height],'k');
112
113
114 xlabel('x'); ylabel('y');
115 h_title = title('t=0.0s');
116
117 axis equal
118 axis([-1.5 1.5 -1.5 1.5]);
119
120 %Step through and update animation
121 for i = 1:length(tspan)
122     % skip frame.
123     if mod(i,10)
124         continue;
125     end
126     t = tspan(i);
127     z = z_trj(:,i);
128     keypoints = keypoints_pend(z,param);
129
130     rA = keypoints(:,1); % Vector to base of cart
131     rB = keypoints(:,2);
132
133     set(h_title,'String',  sprintf('t=%.2f',t) ); % update title
134
135     set(h_OA,'XData',[0 rA(1)]);
136     set(h_OA,'YData',[0 rA(2)]);
137
138     set(h_AB,'XData',[rA(1) rB(1)]);
139     set(h_AB,'YData',[rA(2) rB(2)]);
140
141     pause(.01)
142 end
143
144
145
146 %%
```

```
147
148 function qdot = discrete_impact_contact(z, p, rest_coeff, fric_coeff, yC)
149
150     qdot = z(3:4);
151 % Put your code here
152     pos_foot = position_foot(z, p);
153     Cy = pos_foot(2) - yC;          % foot height relative to ground
154     dCy = velocity_foot(z, p);
155
156     J = jacobian_foot(z, p);
157     M = A_pend(z, p);
158
159     Lambda_inv = J*inv(M)*J.';
160     Lambda = inv(Lambda_inv);
161
162     if(Cy < 0 && dCy(2) < 0)
163         F = Lambda*(-rest_coeff*dCy(2) - J*qdot);    % vertical impulse
164
165         if(F(1) > fric_coeff*F(2))
166            F(1) = fric_coeff*F(2);
167         elseif(F(1) < -fric_coeff*F(2))
168            F(1) = -fric_coeff*F(2);                  % tangential impulse
169         end
170
171         qdot = qdot + inv(M)*transpose(J)*F;
172     end
173 end
174
175 function qdot = joint_limit_constraint(z,p)
176
177     q1_min = -0.1;
178 % Put your code here
179 end
```

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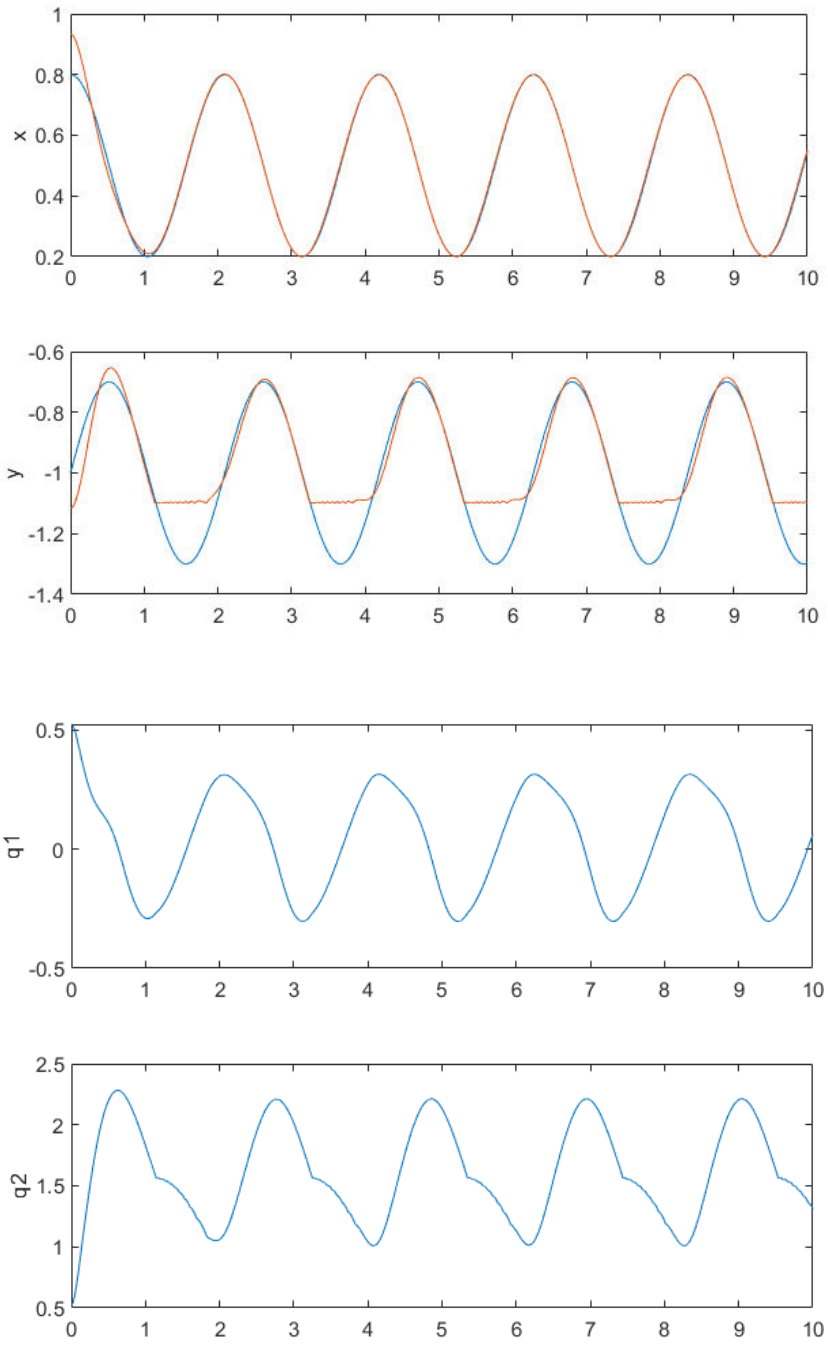
CSS403 HW8

3. $\gamma = 0$, $\mu = 0.3$, $\omega = 3$ rad/s



4. When the friction coefficient is increased, the end effector gets stuck as it hits the ground due to the increased friction. When it powers through and is able to slip free, it accelerates rapidly and drags across the ground plane. \