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%%% MIE301 Lab 3: Optimizing mechanisms
%% part a
close all; % closes all figures
clear all; % clears all variables from memory
clc;       % clears all calculations from the Matlab workspace

% Plot Parameters: these will be used to set the axis limits on the figure
xmin= -20; % leftmost window edge
xmax= 70;  % rightmost window edge
ymin= -25; % bottom window edge
ymax= 75;  % top window edge

% Link Parameters
increments = 200; % number of theta2 configuration steps to calculate along
mechanism rotation %%%% YOU MAY WANT TO CHANGE THIS

max_rotation_theta2 = 360 *pi/180; % rotation limit of theta2, radians
theta2 = linspace(0,max_rotation_theta2,increments); % link 2 rotation into
'increments' number of angles

r1 = 19;          % link 1 length, cm
r2 = 10;          % link 2 length, cm
r3 = 25;          % link 3 length, cm
r4 = 25;          % link 4 length, cm
re=20;            % extension length, cm
a = 0.1 ;         % path slope tolerance
% Rotation time
theta2_dot = 60;                       % rotation rate, rpm
t_rev = 60/theta2_dot;                 % rotation time limit, seconds
time = linspace(0,t_rev,increments);    % link 2 rotation into 'increments' number
of times

% set up figure
figure(1);                             %create new figure
set(1,'WindowStyle','Docked')          %dock the figure
% 4-bar mechanism geometric constants: See textbook section 4.3.3 for derivation.
(Eq. 4.3-54)

% Hint: add a for-loop here to calculate mechanism motion and plot iterate over r3
% recommended range for r3 20:0.5:30

G = []';
r3 = 20:0.5:30;
for x=1:length(r3)
    h1 = r1/r2;
    h2 = r1/r3(x);
    h3 = r1/r4;
    h4 =(-r1^2-r2^2-(r3(x))^2+r4^2)/(2*r2*r3(x));
    h5 =(r1^2+r2^2-(r3(x))^2+r4^2)/(2*r2*r4);
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        for i=1:increments                              % step through motion of the
mechanism
            hold off;

            %  geometric calculations (book eq. 4.3-56 to 4.3-62):
            d = -h1 +(1-h3)*cos(theta2(i)) +h5;
            b = -2*sin(theta2(i));
            e = h1 -(1+h3)*cos(theta2(i)) +h5;
            a_a = -h1 +(1+h2)*cos(theta2(i)) +h4;
            c = h1 -(1-h2)*cos(theta2(i)) +h4;

            theta3_1(i) = 2*atan(((-b-(b^2-4*a_a*c)^0.5)/(2*a_a))); %calculate
angle of link 3 (eq. 4.3-64)
            theta4_1(i) = 2*atan(((-b-(b^2-4*d*e)^0.5)/(2*d)));

            % Link Coordinates calculations:
            Ax(i) = 0;                                          % pivot point of link 2
position
            Ay(i) = 0;                                          % pivot point of link 2
position
            Bx(i) = r2*cos( theta2(i) );                        % point B position
            By(i) = r2*sin( theta2(i) );                        % point B position
            Cx(i,1) = Bx(i) + (r3(x)+re )*cos( theta3_1(i) );               % point C
position. We're going to store these for each extension value (indexed by j)
            Cy(i,1) = By(i) + (r3(x)+re )*sin( theta3_1(i) );               % point C
position
            Dx(i) = r1 + r4*cos( theta4_1(i) );                 % point D position
            Dy(i) = r4*sin( theta4_1(i) );                      % point D
position

            if (false) % put true here to draw the mechanism each time, false to
skip drawing that for increased simulation speed
                plot( [Ax(i) Bx(i)], [Ay(i), By(i)],'Color','r','LineWidth',3 ); %
draw link2
                hold on;
                plot( [Bx(i), Dx(i)], [ By(i), Dy(i)],'Color','b','LineWidth',3 );
% draw link3
                plot( [Dx(i), Cx(i,1)], [ Dy(i),
Cy(i,1)],'Color','b','LineWidth',3 ); % draw link3 extension to point C
                plot( [r1, Dx(i)], [ 0, Dy(i)],'Color','m','LineWidth',3 ); % draw
link4

                % Draw Base Pivots:
                recsz = 2.5;                                            % size of drawn
base pivot
                plot([0,recsz],[0,-recsz],'r');                         % draw base
pivot for link2
                plot([0,-recsz],[0,-recsz],'r');                        % draw base
pivot for link2
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                plot(0,0,'ro','MarkerFaceColor','w');                   % draw a small
circle at the base pivot point
                plot(Bx(i), By(i), 'bo','MarkerFaceColor','w');         % draw a small
circle at B
                text(Bx(i)+0.9, By(i), 'B','color','b');                % label point B

                plot([r1,r1+recsz],[0,-recsz],'r');                     % draw base
pivot for link4
                plot([r1,r1-recsz],[0,-recsz],'r');                     % draw base
pivot for link4
                plot(r1,0,'ro','MarkerFaceColor','w');                  % draw a small
circle at the base pivot point
                plot(Dx(i), Dy(i), 'bo','MarkerFaceColor','w');         % draw a small
circle at D
                text(Dx(i)+0.9, Dy(i), 'D','color','b');                % label point D
                text(Cx(i,1)+0.9, Cy(i,1), 'C','color','b');            % label point C

                xlabel('x (cm)', 'fontsize', 15);   % axis label
                ylabel('y (cm)', 'fontsize', 15);   % axil label
                title('Lab3 - starter');            % add a title to the figure
                axis equal;                         % make sure the figure is not
stretched
                grid on;
                axis( [xmin xmax ymin ymax] );      % figure axis limits
            end
            %pause(0.1);                            % wait to proceed to next
configuration, seconds
        end
         %pause(.01); %pause after drawing the current and previous paths, seconds



    % compute slope on point c path
    for i=1:1:length(Cx)
        if i==1
        s(i)=(Cy(2)-Cy(end))/(Cx(2)-Cx(end));
        elseif i==length(Cx)
        s(i)=(Cy(1)-Cy(end-1))/(Cx(1)-Cx(end-1));
        else
        s(i)=(Cy(i+1)-Cy(i-1))/(Cx(i+1)-Cx(i-1));
        end
    end
    % get the very left and right points on point c path
    index_left=find(Cx==max(Cx));
    index_right=find(Cx==min(Cx));

    k = find(abs(s) < a); % find the poins with slope smaller than a
    k_bottom=k(k<index_right & k>index_left);% select the points at the bottom of
the path
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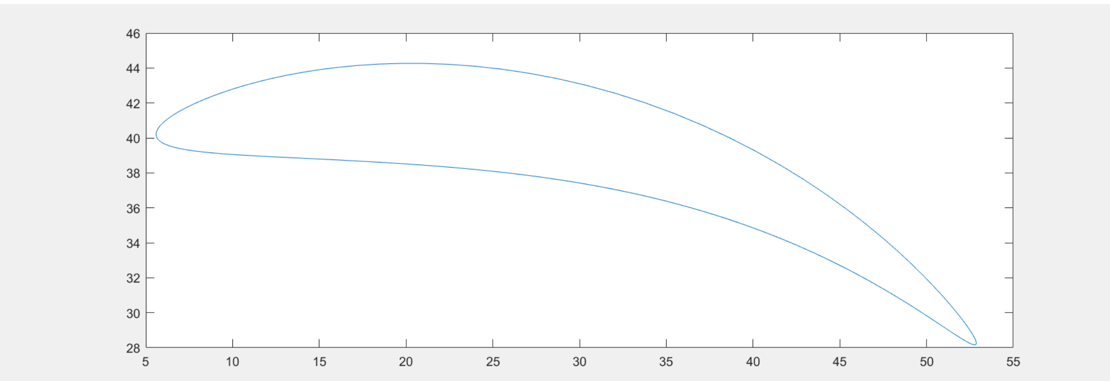
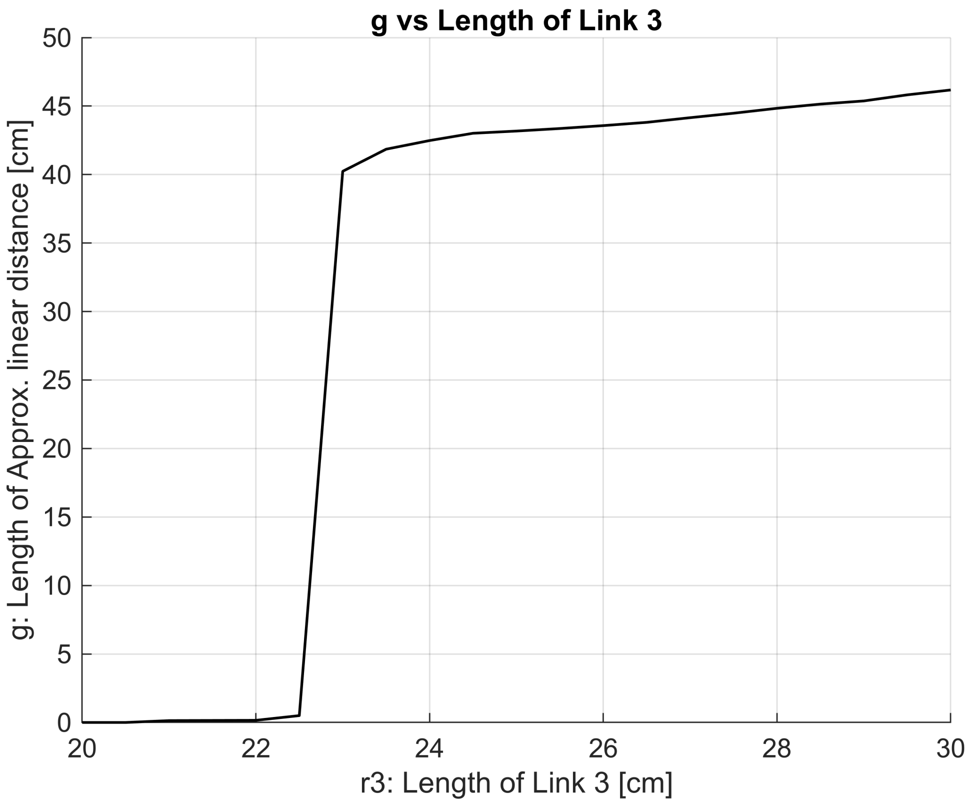
```
    % compute length of straight portion

    g=0;
    k_start=k_bottom(1);
    k_end=k_bottom(end);
    for j=k_start:1:k_end-1
        g_=((Cx(j+1)-Cx(j))^2+(Cy(j+1)-Cy(j))^2)^0.5;
        g=g+g_;

    end

    % plot the point c path
    plot(Cx,Cy)

    G = [G; g];
end
```




```
% todo: plot g as function r3

figure;
hold on;
grid on;
plot(r3, G',"Color",'black', 'LineWidth',1);
title('g vs Length of Link 3');
xlabel('r3: Length of Link 3 [cm]');
ylabel('g: Length of Approx. linear distance [cm]');
hold off;
```

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[Max_g, i] = max(G)
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Max_g = 46.1749
i = 21
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r3_for_max_g = r3(i)
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```
r3_for_max_g = 30
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```
k1 = r3
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```
k1 = 1×21
   20.0000   20.5000   21.0000   21.5000   22.0000   22.5000   23.0000   23.5000 ⋯
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```
k2 = G
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```
k2 = 21×1
         0
         0
    0.1359
    0.1466
    0.1570
    0.5004
   40.2374
   41.8521
   42.4823
   43.0144
      ⋮
```

```
%% part b - Plot the optimized trace; with the straight line portion precisely
marked.
% Include the optimized mechanism links.
% first find the max g and its corresponding r3

%% part c - Input link angle?

%% part d - Max and min speed and acceleration of the trace point C through the
straight portion?
% Hint: distance between C(i+1) and C(i-1) devided by 2 delta_t can give
% you an approximation of speed at point C(i)
% acceleration = change in speed/change in time

%% part e - How does the tolerance (a) affect your optimized path length?

% Hint: Similar to part a,but add an outer loop and iterate over a instead of r3
```