**ENM221-0040/2020**

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A four bar linkage is required to generate the following function,

$$\theta_4 = 65 + 0.43\theta_2$$

for $15^0 \leq \theta_2 \leq 165^0$. Where $\theta_2$ and $\theta_4$ define the rotation angles of the input and output links respectively. It is further required that the length of the fixed link be $410mm$.

Write a computer program in any language to,

**(a)** Evaluate the link lengths ratios $K_1$, $K_2$ and $K_3$ using three precision points, and hence determine the lengths of the other links. Use Chebyshev's spacing. Determine the transmission angles for the given range of input angles and at an increment of $5^0$, and plot the variation of the transmission angles with the input angles. Comment on the quality of transmission of the linkage.

```
%PART A---------------------------------------------------------------------
% Defining the function
theta2 = linspace(15, 165, 30);
theta4 = 65 + 0.43*theta2;
format short g %to prevent e from forming in the output

% Defining the fixed link length
L1 = 410;

% Precision points using Chebyshev Spacing
precision_point=precise(15,165,3);% Using the function precise point function
theta4_p = 65 + 0.43*precision_point;
thetapp_4=precision_point-theta4_p
% Use Chebyshev's spacing to evaluate the link length ratios K1, K2, and K3
% Freudeinstein's Equation :K1cos(theta4)-K2cos(theta2)+K3=cos(theta2-theta4)
vals=[cosd(theta4_p),cosd(precision_point),[1;1;1]];
fin=[cosd(thetapp_4)];
% Using Matrix
ans=vals\fin

K1=ans(1)
K2=ans(2)
K3=ans(3)


% Determine the lengths of the other links
L2 = abs(L1/K1) %a
L3 = abs(L1/K2) %c
L4 = sqrt(abs(K3*(2*L2*L3)-L2.^2-L3.^2-L1.^2))%b


% Compute the transmission angles for the given range of input angles
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```
transmission_angles = acosd(abs((L4.^2 +L3.^2 - L2.^2-
L1.^2+((2.*L2.*L1).*cosd(theta2)))./(2.*L4.*L3)));

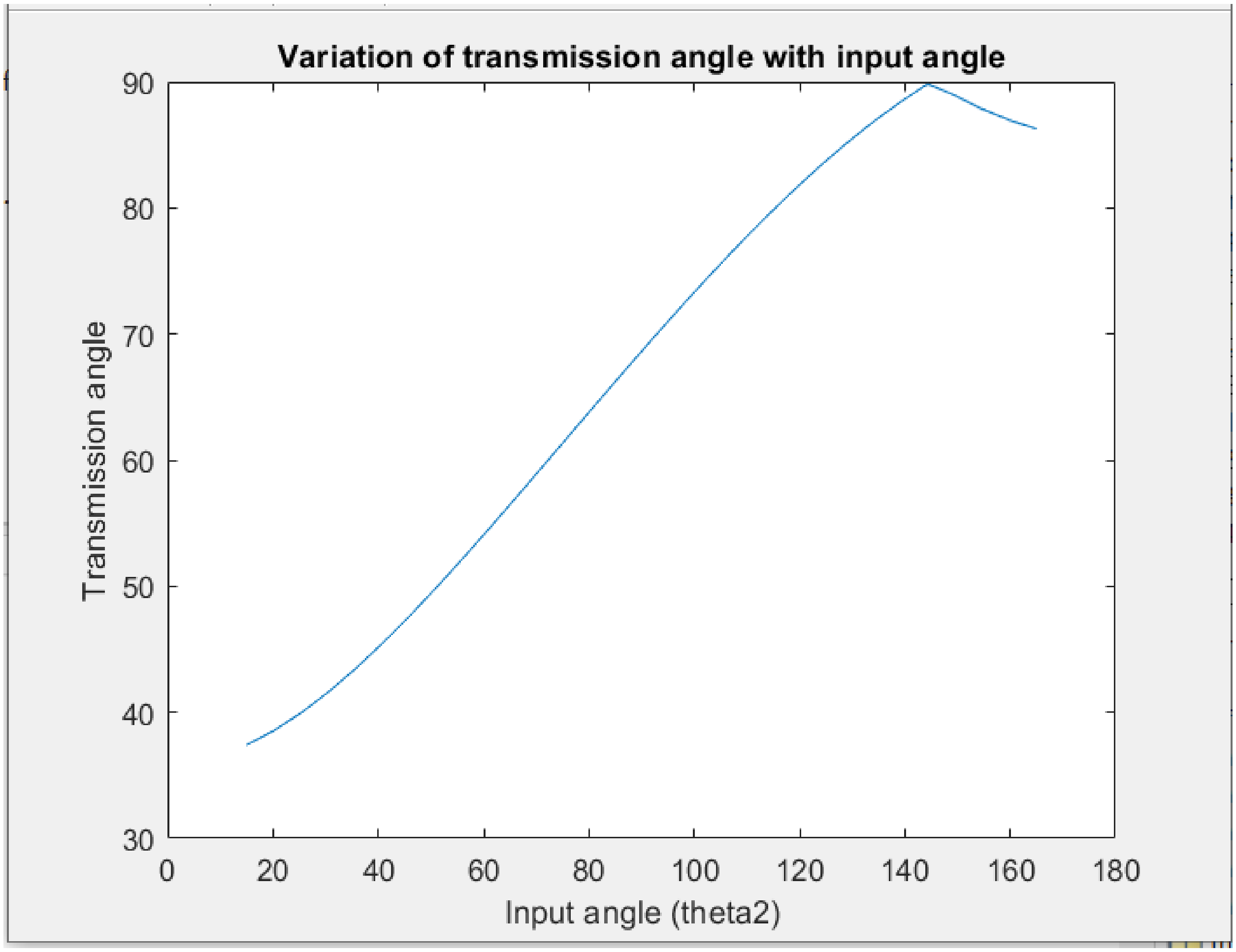
% Plot the variation of the transmission angles with the input angles
plot(theta2, transmission_angles);
xlabel('Input angle (theta2)');
ylabel('Transmission angle');
title('Variation of transmission angle with input angle');


%Structural Error
theta2struc = linspace(15, 165, 30);
A=(1-K2).*cosd(theta2struc)-K1+K3;
B=-2*sind(theta2struc);
C=K1-((1+K2).*cosd(theta2struc))+K3;
theta4generated=2*atand((-B+sqrt((B.^2)-(4.*(A.*C))))./(2.*A));
theta4required=65 + 0.43*theta2struc;
error=theta4required-theta4generated
plot(theta2struc,error);
ylabel('error');
xlabel('Input Angle');
title('Structural Error Graphs - Lab1 a');


%Chebyshev Spacing Function
function precision_point=precise(theta_2init,theta_2final,n)
    precision_point=[];
    for c = 1:n
        theta_2pp = 0.5*(theta_2init+theta_2final)-0.5*(theta_2final-
theta_2init).*cosd(180*(2*(c)-1)/(2*n));
        precision_point(end+1)=theta_2pp;
    end
    precision_point=precision_point.';
end
```

**K1 = -7.1003 K2 = 3.4091 K3 =-0.71008**

**L2 = 57.744 L3 =120.27 L4 = 442.45**




The transmission lies between $40^0$ and $140^0$, this indicates the it's **smooth**.

**(b)** Evaluate the link lengths ratios $K_1$, $K_2$ and $K_3$ using the least square method for five precision points, and hence determine the length of the other links. Use Chebyshev's spacing.

```
%PART B------------------------------------------------------------------
%Using the Least Square Method
% Defining the fixed link length
L1 = 410;

precision_point=precise(15,165,5)
theta4 = 65 + 0.43*precision_point;

%Matrix of the Least Square Method Formula
a = [sum((cosd(theta4)).^2), -sum(cosd(precision_point).*cosd(theta4)),
sum(cosd(theta4));
    sum(cosd(theta4).*cosd(precision_point)), -sum((cosd(precision_point)).^2),
sum(cosd(precision_point));
    sum(cosd(theta4)), -sum(cosd(precision_point)),5];
```

```
b = [(sum(cosd(theta4).*cosd(precision_point-theta4)));
    (sum(cosd(precision_point).*cosd(precision_point-theta4)));
    (sum(cosd(precision_point-theta4)))];

x = a\b;

% Link length ratios
K1 = x(1);
K2 = x(2);
K3 = x(3);

% Determine the lengths of the other links
L2 = abs(L1/K1) %a
L3 = abs(L1/K2) %c
L4 = sqrt(abs(K3*(2*L2*L3)-L2.^2-L3.^2-L1.^2))%b


%Structural Error
theta2struc = linspace(15, 165, 30);

A=(1-K2).*cosd(theta2struc)-K1+K3;
B=-2*sind(theta2struc);
C=K1-((1+K2).*cosd(theta2struc))+K3;

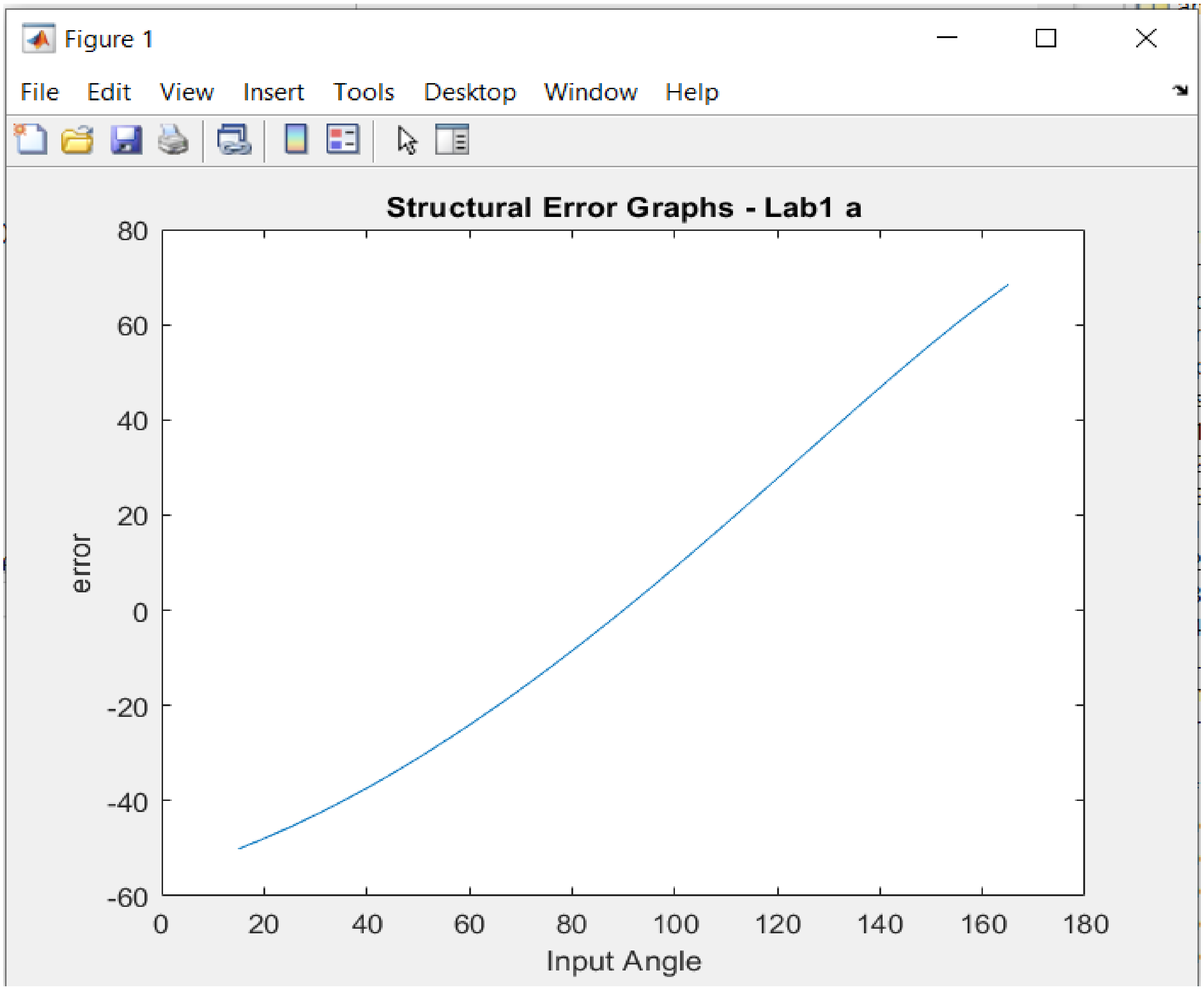
theta4generated=2*atand((-B+sqrt((B.^2)-(4.*(A.*C))))./(2.*A));
theta4required=65 + 0.43*theta2struc;
error=theta4required-theta4generated
plot(theta2struc,error);
ylabel('error');
xlabel('Input Angle');
title('Structural Error Graphs- Lab1 b');

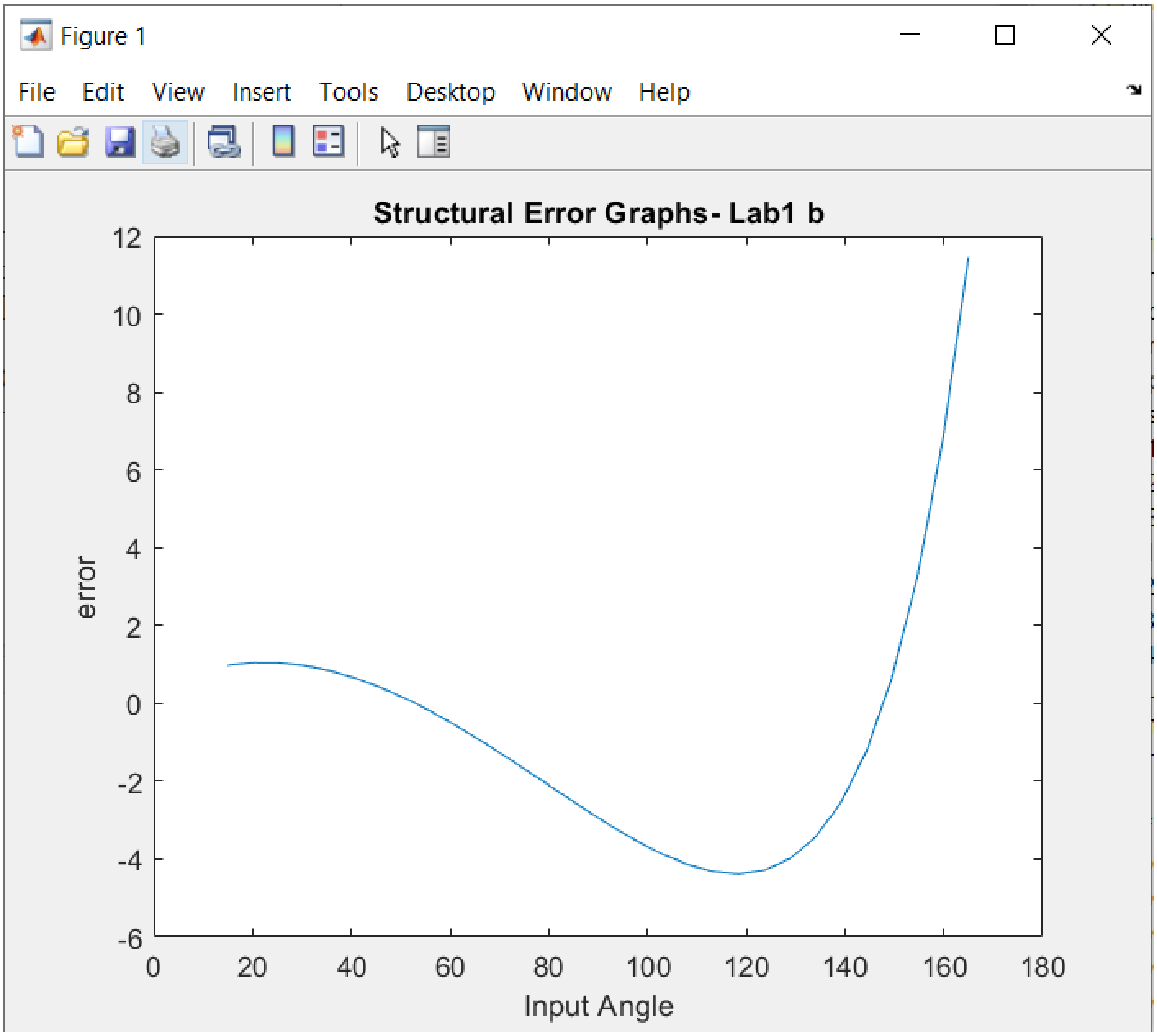

%Chebyshev Spacing function
function precision_point=precise(theta_2init,theta_2final,n)
    precision_point=[];
    for c = 1:n
        theta_2pp = 0.5*(theta_2init+theta_2final)-0.5*(theta_2final-
theta_2init).*cosd(180*(2*(c)-1)/(2*n));
        precision_point(end+1)=theta_2pp;
    end
    precision_point=precision_point.';
end
```

**K1= -1.72930283348066** **K2 = -0.706090707561704** **K3 = 0.463202731752512**

**L2 = 237.09** **L3 = 580.66** **L4 = 658.74**

**(c)** Calculate the structural errors throughout the given range of input angles and at an increment of $5^0$ for the two cases in (a) and (b). Plot the variation of the structural errors as a function of the input angles for the two cases and in the same axis. Comment on the results.






The method of Least Square is more accurate since its error gradually reduces and increases depending on the angle while the precision point method increases with increase in input angle meaning the larger the angle the larger the error.