ME 581 – C02 **Name** ________________________

1) Program your constraints and Jacobian for the web cutter into a Newton-Raphson iterative algorithm to solve position kinematics for any desired crank angle. To check your work, when ϕ_2=90 degrees, ϕ_3 = 65.3 degrees and ϕ_4 = -69.0 degrees.

2) Develop the velocity right-hand-side vector $\{\nu\}$ for your constraints, and program them to solve for the generalized coordinate velocities $\{\dot{q}\}$. To check your work, when ϕ_2 = 90 degrees, $\dot{\phi}_3$ = 0.88 rad/s CW and $\dot{\phi}_4$ = 0.72 rad/s CCW.

3) Develop the acceleration right-hand-side vector $\{\gamma\}$ for your constraints, and program them to solve for the generalized coordinate accelerations $\{\ddot{q}\}$. To check your work, when ϕ_2 = 90 degrees, $\ddot{\phi}_3$ = 14.2 rad/s/s CCW and $\ddot{\phi}_4$ = 10.1 rad/s/s CCW.

4) Place your position, velocity and acceleration algorithms within an outer loop to drive the crank through one complete revolution, and plot $\ddot{\phi}_4$ as a function of crank angle. Also plot the determinant of your Jacobian as a function of crank angle. Start the crank at ϕ_2 = 0 degrees in your plots.

5) Determine the speed of the web.

V_{WEB} < 9.37 cps

EXTRA CREDIT
Modify your code to simulate an in-line slider crank with R = 4.00 cm and L = 14.23 cm operating at constant 60 rpm CCW crank speed. Validate your results by plotting piston acceleration as a function of crank angle compared to simple geometric equations.

Closing $\phi_2 = 85.5^o$

$$\{r_3\}^P = \begin{Bmatrix} 18.0651\text{ cm} \\ 13.8931\text{ cm} \end{Bmatrix} \quad \{r_4\}^Q = \begin{Bmatrix} 18.0993\text{ cm} \\ 13.8936\text{ cm} \end{Bmatrix} \quad \{\dot{r}_3\}^P = \begin{Bmatrix} -14.50\text{ cps} \\ -16.95\text{ cps} \end{Bmatrix} \quad \{\dot{r}_4\}^Q = \begin{Bmatrix} -9.37\text{ cps} \\ 2.88\text{ cps} \end{Bmatrix}$$

Opening $\phi_2 = 257.4^o$

$$\{r_3\}^P = \begin{Bmatrix} 8.7160\text{ cm} \\ 14.0208\text{ cm} \end{Bmatrix} \quad \{r_4\}^Q = \begin{Bmatrix} 8.7511\text{ cm} \\ 14.0194\text{ cm} \end{Bmatrix} \quad \{\dot{r}_3\}^P = \begin{Bmatrix} -16.73\text{ cps} \\ +16.59\text{ cps} \end{Bmatrix} \quad \{\dot{r}_4\}^Q = \begin{Bmatrix} -10.33\text{ cps} \\ -2.87\text{ cps} \end{Bmatrix}$$

```
% sc_geometric.m - in-line slider crank geometric equations
% HJSIII, 14.02.22

clear

% constants
d2r = pi / 180;

% geometry and driver
R = 4;                  % crank length [inch]
L = 14.23;              % connecting rod length [inch[
w = 60 * 2*pi / 60;     % constant crank speed - 60 rpm CCW converted to rad/sec

% constant speed rotation driver motion
theta_deg = ( 0 : 6 : 360 )';
theta = theta_deg * d2r;
st = sin(theta);
ct = cos(theta);

thetad = w * ones( size( theta ) );
thetadd = zeros( size( theta ) );

% position
phi = asin( R * sin(theta) / L );
sp = sin(phi);
cp = cos(phi);

phid = R*thetad.*ct ./ (L*cp);
sd = -R*thetad.*st -L*phid.*sp;

phidd = ( R*thetadd.*ct -R*thetad.*thetad.*st +L*phid.*phid.*sp ) ./ (L*cp);
sdd = -R*thetadd.*st -R*thetad.*thetad.*ct -L*phidd.*sp -L*phid.*phid.*cp;

figure( 1 )
  plot( theta_deg, sdd, 'r' )
  axis( [ 0 360 -250 150 ] )
  title( 'Slider crank geometric solution - 60 rpm CCW' )
  xlabel( 'Crank angle [deg]' )
  ylabel( 'Piston acceleration [ipss]' )

% bottom of sc_geometric
```

$$\{\Phi\} = \begin{Bmatrix} \{\Phi\}_{KINEMATIC} \\ \{\Phi\}_{DRIVER} \end{Bmatrix} = \begin{Bmatrix} \{\Phi\}_{REV\_A} \\ \{\Phi\}_{REV\_B} \\ \{\Phi\}_{REV\_C} \\ \{\Phi\}_{REV\_D} \\ \Phi_{DRIVER} \end{Bmatrix} = \begin{Bmatrix} \{r_2\}^A - \{r_1\}^A \\ \{r_3\}^B - \{r_2\}^B \\ \{r_4\}^C - \{r_3\}^C \\ \{r_4\}^D - \{r_1\}^D \\ \phi_2 - \phi_{2\_START} - \omega_2 t \end{Bmatrix} = \{0\}$$

$$[\Phi_q]\{\dot{q}\} = \begin{Bmatrix} \{\nu\}_{KINEMATIC} \\ \{\nu\}_{DRIVER} \end{Bmatrix} = \begin{Bmatrix} \{\nu\}_{REV\_A} \\ \{\nu\}_{REV\_B} \\ \{\nu\}_{REV\_C} \\ \{\nu\}_{REV\_D} \\ \nu_{DRIVER} \end{Bmatrix} = \begin{Bmatrix} \{0_{2x1}\} \\ \{0_{2x1}\} \\ \{0_{2x1}\} \\ \{0_{2x1}\} \\ \omega_2 \end{Bmatrix}$$

$$\{\dot{q}\} = [\Phi_q]^{-1} \begin{Bmatrix} \{0_{8x1}\} \\ \omega_2 \end{Bmatrix}$$

$$\{\Phi\}_{REV} = \{r_{Pj}\} - \{r_{Pi}\} = \{0_{2x1}\}$$

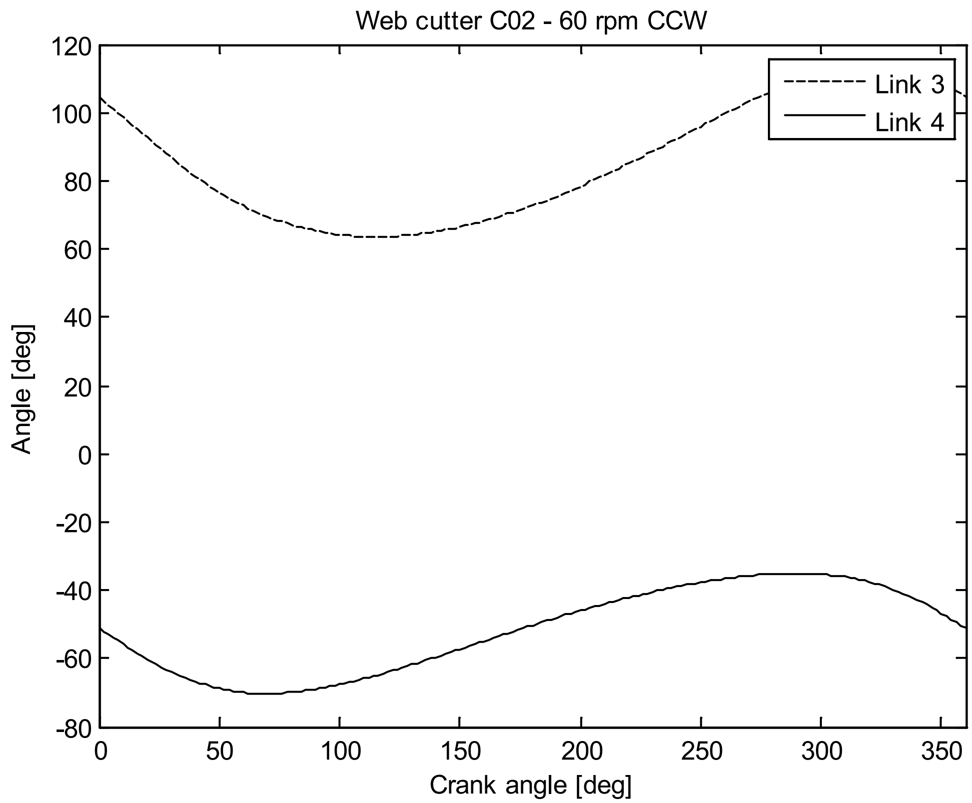
$$\{\gamma\}_{REV} = \dot{\phi}_j^{\,2}[A_j]\{s_j\}'^P - \dot{\phi}_i^{\,2}[A_i]\{s_i\}'^P \qquad \{\gamma\}_{DRIVER} = -\{\Phi_{tt}\}$$

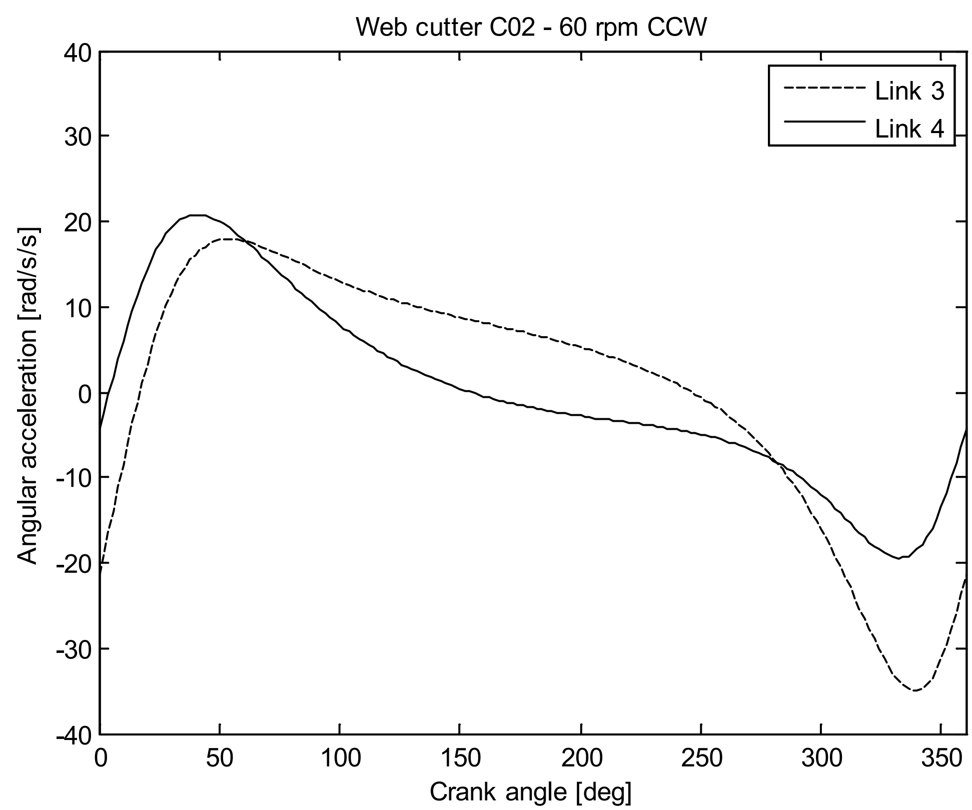
$$[\Phi_q]\{\ddot{q}\} = \begin{Bmatrix} \{\gamma\}_{KINEMATIC} \\ \{\gamma\}_{DRIVER} \end{Bmatrix} = \begin{Bmatrix} \{\gamma\}_{REV\_A} \\ \{\gamma\}_{REV\_B} \\ \{\gamma\}_{REV\_C} \\ \{\gamma\}_{REV\_D} \\ \gamma_{DRIVER} \end{Bmatrix} = \begin{Bmatrix} \dot{\phi}_2^{\,2}[A_2]\{s_2\}'^A \\ \dot{\phi}_3^{\,2}[A_3]\{s_3\}'^B - \dot{\phi}_2^{\,2}[A_2]\{s_2\}'^B \\ \dot{\phi}_4^{\,2}[A_4]\{s_4\}'^C - \dot{\phi}_3^{\,2}[A_3]\{s_3\}'^C \\ \dot{\phi}_4^{\,2}[A_4]\{s_4\}'^D \\ 0 \end{Bmatrix}$$

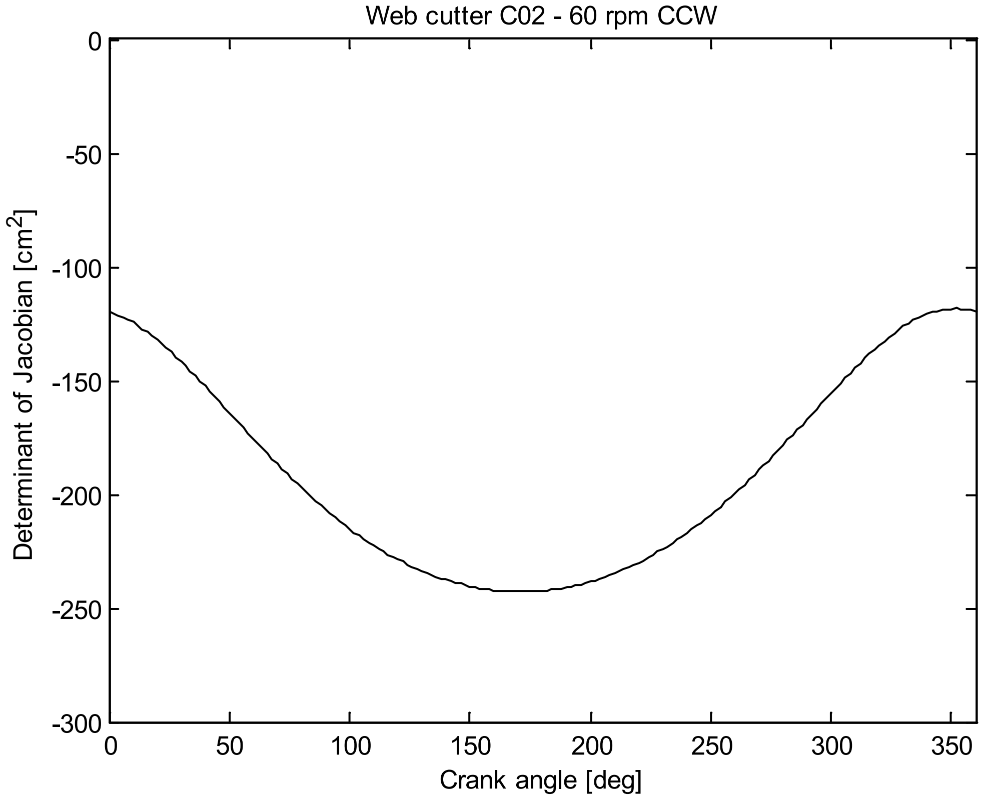
$$\{\ddot{q}\} = [\Phi_q]^{-1}\{\gamma\}$$

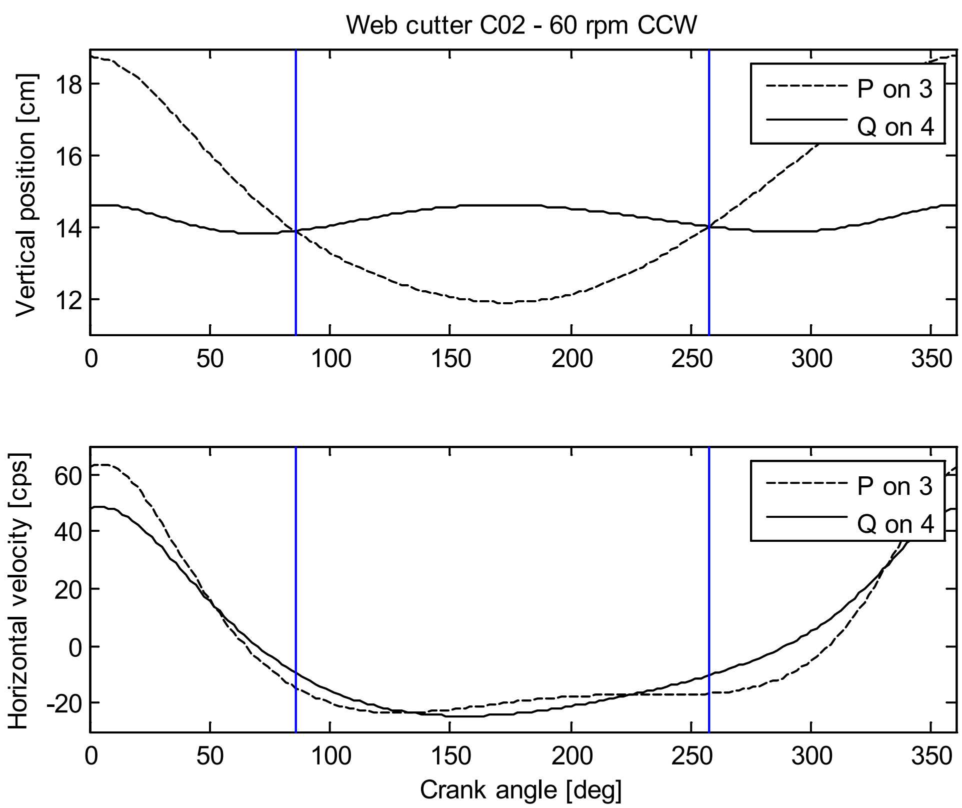
$$\{\dot{r}_3\}^P = \{\dot{r}_3\} + \dot{\phi}_3[B_3]\{s_3\}'^P \qquad \{\dot{r}_4\}^Q = \{\dot{r}_3\} + \dot{\phi}_4[B_4]\{s_4\}'^Q$$

ME 581 – C02 **Name __________________________**

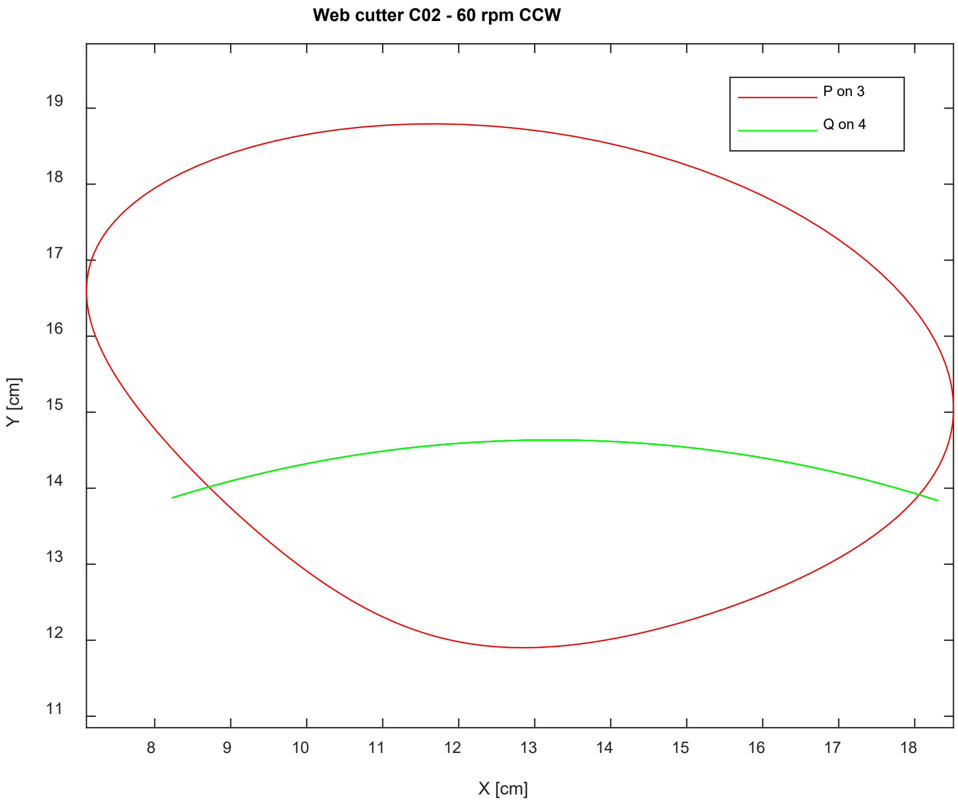





Web cutter C02 - 60 rpm CCW
Determinant of Jacobian [cm^2]
0
-50
-100
-150
-200
-250
-300
0
50
100
150
200
250
300
350
Crank angle [deg]


Web cutter C02 - 60 rpm CCW
Vertical position [cm]
18
16
14
12
P on 3
Q on 4
0
50
100
150
200
250
300
350
Horizontal velocity [cps]
60
40
20
0
-20
P on 3
Q on 4
0
50
100
150
200
250
300
350
Crank angle [deg]

ME 581 – C02 **Name ______________________**



```
% wc_main_c02.m - web cutter four-bar for ME 581
%   main for Computer 2
% HJSIII, 22.02.16

clear

% general constants
d2r = pi / 180;
R = [ 0 -1; 1 0 ];

% initialize
wc_ini_c01

% starting position
phi2_start = 0 * d2r;  % start at zero
%phi2_start = 30 * d2r;  % position in line drawing
%phi2_start = 90 * d2r;  % check at 90 degrees
%phi2_start =  85.5 * d2r;  % cutter closing
%q = [ 0  0  4.4925  -0.8726  -3.9037  1.7233  -3.0341  10.1612  -0.6438]'; % q at opening
%phi2_start =  257.4 * d2r;  % cutter opening

% time loop
%tpr = 0;                        % single poisition
tpr = 2 * pi / w2;              % one revolution at constant speed
t_start = 0;                    % start
t_end = tpr;                    % end
nt = 180;                       % number of time steps
dt = (t_end - t_start) / nt;

keep_q = [];
keep = [];
for t = t_start : dt : t_end;

% kinematics
  wc_kin

% save kinematics
  detJAC = det(JAC);
  x3P = r3P(1);
  y3P = r3P(2);
  x4Q = r4Q(1);
  y4Q = r4Q(2);
  x3Pd = r3Pd(1);
  x4Qd = r4Qd(1);

  keep_q = [ keep_q ; q'  qd'  qdd' ];
  keep = [ keep ; detJAC  x3P  y3P  x4Q  y4Q  x3Pd  x4Qd ];

% bottom - for t
end

% plot
ang2 = keep_q(:,3) /d2r;
ang3 = keep_q(:,6) /d2r;
ang4 = keep_q(:,9) /d2r;
phi3dd = keep_q(:,24);
phi4dd = keep_q(:,27);
detJAC = keep(:,1);
x3P = keep(:,2);
y3P = keep(:,3);
x4Q = keep(:,4);
y4Q = keep(:,5);
x3Pd = keep(:,6);
x4Qd = keep(:,7);

figure( 1 )
  clf
  plot( ang2,ang3,'k--', ang2,ang4,'k-' )
  axis( [ 0 360 -80 120 ] )
  title( 'Web cutter C02 - 60 rpm CCW' )
  xlabel( 'Crank angle [deg]' )
```

```
  ylabel( 'Angle [deg]' )
  legend( 'Link 3', 'Link 4' )

figure( 2 )
  clf
  plot( ang2,phi3dd,'k--', ang2,phi4dd,'k-' )
  axis( [ 0 360 -40 40 ] )
  title( 'Web cutter C02 - 60 rpm CCW' )
  xlabel( 'Crank angle [deg]' )
  ylabel( 'Angular acceleration [rad/s/s]' )
  legend( 'Link 3', 'Link 4' )

figure( 3 )
  clf
  plot( ang2,detJAC,'k' )
  axis( [ 0 360 -300 0 ] )
  title( 'Web cutter C02 - 60 rpm CCW' )
  xlabel( 'Crank angle [deg]' )
  ylabel( 'Determinant of Jacobian [cm^2]' )

figure( 4 )
  clf
  subplot( 2, 1, 1 )
    plot( ang2,y3P,'k--', ang2,y4Q,'k-' )
    hold on
    plot( [ 85.5 85.5 NaN 257.4 257.4 ], [ 11 19 NaN 11 19 ], 'b' )
    axis( [ 0 360 11 19 ] )
    title( 'Web cutter C02 - 60 rpm CCW' )
%    xlabel( 'Crank angle [deg]' )
    ylabel( 'Vertical position [cm]' )
    legend( 'P on 3', 'Q on 4' )

  subplot( 2, 1, 2 )
    plot( ang2,x3Pd,'k--', ang2,x4Qd,'k-' )
    hold on
    plot( [ 85.5 85.5 NaN 257.4 257.4 ], [ -30 70 NaN -30 70 ], 'b' )
    axis( [ 0 360 -30 70 ] )
%    title( 'Web cutter C02 - 60 rpm CCW' )
    xlabel( 'Crank angle [deg]' )
    ylabel( 'Horizontal velocity [cps]' )
    legend( 'P on 3', 'Q on 4' )

figure( 5 )
  clf
  plot( x3P,y3P,'r', x4Q,y4Q,'g' )
  axis equal
  title( 'Web cutter C02 - 60 rpm CCW' )
  xlabel( 'X [cm]' )
  ylabel( 'Y [cm]' )
  legend( 'P on 3', 'Q on 4' )

% save position data for animation
save wc_q.txt keep_q -ascii

% bottom - wc_main_c02
```

Same code for

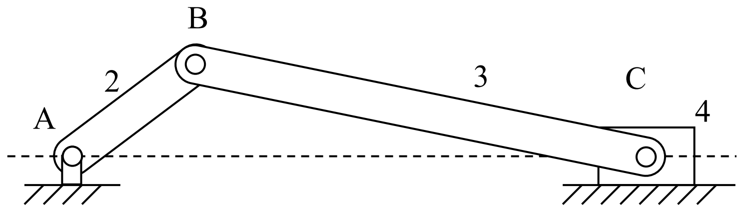
wc_ini_c01.m
wc_phi.m

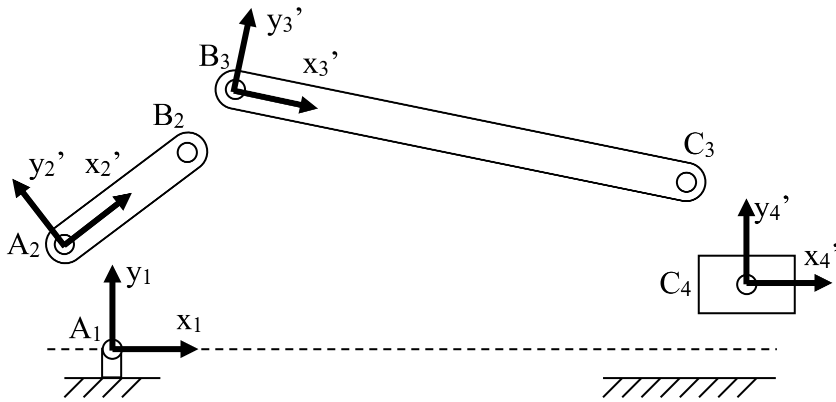
ME 581 – C02

Name ________________________

```
% wc_kin.m - web cutter four-bar for ME 581
%   positon, velocity, and acceleration
% HJSIII, 22.02.16

% Newton-Raphson position solution
assy_tol = 1e-5;
wc_phi
while max(abs(PHI)) > assy_tol,
  q = q - inv(JAC) * PHI;
  wc_phi
end

% velocity
velrhs = zeros(9,1);
velrhs(9) = w2;
qd = inv(JAC) * velrhs;

% global velocities of points
r2d = qd(1:2);
r3d = qd(4:5);
r4d = qd(7:8);
phi2d = qd(3);
phi3d = qd(6);
phi4d = qd(9);
r3Pd = r3d + phi3d*B3*s3pP;
r4Qd = r4d + phi4d*B4*s4pQ;

% acceleration
accrhs = zeros(9,1);
accrhs(1:2) = A2*s2pA*phi2d*phi2d;
accrhs(3:4) = A3*s3pB*phi3d*phi3d - A2*s2pB*phi2d*phi2d;
accrhs(5:6) = A4*s4pC*phi4d*phi4d - A3*s3pC*phi3d*phi3d;
accrhs(7:8) = A4*s4pD*phi4d*phi4d;
accrhs(9)=0;
qdd = inv(JAC) * accrhs;

% global accelerations
r2dd = qdd(1:2);
r3dd = qdd(4:5);
r4dd = qdd(7:8);
phi2dd = qdd(3);
phi3dd = qdd(6);
phi4dd = qdd(9);

% bottom - wc_kin
```

ME 581 – C02 **Name ________________________**





AB = R = 4 cm
BC = L = 14.23 cm
x_2 axis along centerline of link 2
x_3 axis along centerline of link 3
ω_2 = 60 rpm CCW constant

<u>blueprint information</u>

$$\{s_2\}'^A = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix} \qquad \{s_2\}'^B = \begin{Bmatrix} R \\ 0 \end{Bmatrix} \qquad \{s_3\}'^B = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix} \qquad \{s_3\}'^C = \begin{Bmatrix} L \\ 0 \end{Bmatrix} \qquad \{s_4\}'^C = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix} \qquad \{r_1\}^A = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}$$

<u>adjust</u> $\{r_2\} \quad \phi_2 \quad \{r_3\} \quad \phi_3 \quad \{r_4\} \quad \phi_4$

<u>check</u> $\{r_2\}^A = \{r_1\}^A \qquad \{r_3\}^B = \{r_2\}^B \qquad \{r_4\}^C = \{r_3\}^C \qquad y_4 = 0 \qquad \phi_4 = 0$

<u>driver</u> $\phi_2 = \omega_2 t$

$$\{\Phi\} = \begin{Bmatrix} \{\Phi\}_{KINEMATIC} \\ \{\Phi\}_{DRIVER} \end{Bmatrix} = \begin{Bmatrix} \{\Phi\}_{REV\_A} \\ \{\Phi\}_{REV\_B} \\ \{\Phi\}_{REV\_C} \\ \{\Phi\}_{SLIDER} \\ \Phi_{DRIVER} \end{Bmatrix} = \begin{Bmatrix} \{r_2\}^A - \{r_1\}^A \\ \{r_3\}^B - \{r_2\}^B \\ \{r_4\}^C - \{r_3\}^C \\ \begin{Bmatrix} y_4 \\ \phi_4 \end{Bmatrix} \\ \phi_2 - \omega_2 t \end{Bmatrix} = \{0\}$$

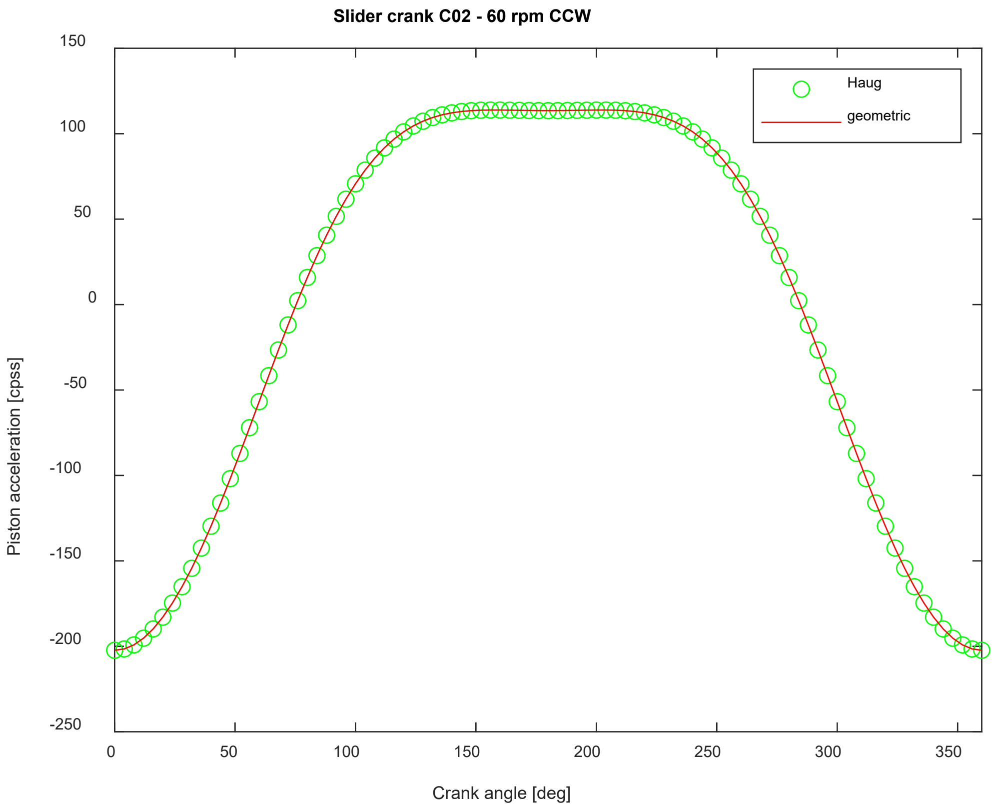
$$[\Phi_q]=\begin{bmatrix} [I_2] & [B_2]\{s_2\}'^A & [0_{2x2}] & [0_{2x1}] & [0_{2x2}] & [0_{2x1}] \\ -[I_2] & -[B_2]\{s_2\}'^B & [I_2] & [B_3]\{s_3\}'^B & [0_{2x2}] & [0_{2x1}] \\ [0_{2x2}] & [0_{2x1}] & -[I_2] & -[B_3]\{s_3\}'^C & [I_2] & [B_4]\{s_4\}'^C \\ [0_{2x2}] & [0_{2x1}] & [0_{2x2}] & [0_{2x1}] & \begin{bmatrix}0 & 1\\ 0 & 0\end{bmatrix} & \begin{Bmatrix}0\\1\end{Bmatrix} \\ [0_{1x2}] & 1 & [0_{1x2}] & 0 & [0_{1x2}] & 0 \end{bmatrix}$$

$$[\Phi_q]\{\dot{q}\}=\begin{Bmatrix}\{\nu\}_{KINEMATIC}\\ \{\nu\}_{DRIVER}\end{Bmatrix}=\begin{Bmatrix}\{\nu\}_{REV\_A}\\ \{\nu\}_{REV\_B}\\ \{\nu\}_{REV\_C}\\ \{\nu\}_{SLIDER}\\ \nu_{DRIVER}\end{Bmatrix}=\begin{Bmatrix}\{0_{2x1}\}\\ \{0_{2x1}\}\\ \{0_{2x1}\}\\ \{0_{2x1}\}\\ \omega_2\end{Bmatrix}$$

$$[\Phi_{q4}]^{SLIDER}=\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix} \qquad [\Phi_{q4}]\{\dot{q}_4\}=\begin{Bmatrix}\dot{y}_4\\ \dot{\phi}_4\end{Bmatrix} \qquad \left([\Phi_{q4}]\{\dot{q}_4\}\right)_{q4}=\begin{Bmatrix}0\\0\end{Bmatrix} \qquad \{\gamma\}^{SLIDER}=\begin{Bmatrix}0\\0\end{Bmatrix}$$

$$[\Phi_q]\{\ddot{q}\}=\begin{Bmatrix}\{\gamma\}_{KINEMATIC}\\ \{\gamma\}_{DRIVER}\end{Bmatrix}=\begin{Bmatrix}\{\gamma\}_{REV\_A}\\ \{\gamma\}_{REV\_B}\\ \{\gamma\}_{REV\_C}\\ \{\gamma\}_{SLIDER}\\ \gamma_{DRIVER}\end{Bmatrix}=\begin{Bmatrix}\dot{\phi}_2^{\,2}[A_2]\{s_2\}'^A\\ \dot{\phi}_3^{\,2}[A_3]\{s_3\}'^B-\dot{\phi}_2^{\,2}[A_2]\{s_2\}'^B\\ \dot{\phi}_4^{\,2}[A_4]\{s_4\}'^C-\dot{\phi}_3^{\,2}[A_3]\{s_3\}'^C\\ \{0_{2x1}\}\\ 0\end{Bmatrix}$$

ME 581 – C02 **Name ________________________**



ME 581 – C02 Name ________________________

```matlab
% sc_main.m - slider crank for ME 581 extra credit C02
%   main for Computer 2
% HJSIII, 20.03.04

clear

% general constants
d2r = pi / 180;
R = [ 0 -1; 1 0 ];

% initialize
sc_ini

% time loop
tpr = 2 * pi / w2;              % one revolution at constant speed
t_start = 0;                    % start
t_end = tpr;                    % end
nt = 180;                       % number of time steps
dt = (t_end - t_start) / nt;

keep_q = [];
for t = t_start : dt : t_end;

% kinematics
  sc_kin

% save kinematics
  keep_q = [ keep_q ; q'  qd'  qdd' ];

% bottom - for t
end

% values for plotting
phi2 = keep_q(:,3);
phi2_deg = phi2 /d2r;
x4dd = keep_q(:,25);

% geometric equations
R = R_link2;
L = L_link3;
theta = phi2;
st = sin(theta);
ct = cos(theta);

theta = phi2;
phi = asin( R * sin(theta) / L );
sp = sin(phi);
cp = cos(phi);

thetad = w2 *  ones( size( theta ) );
phid = R*thetad.*ct ./ (L*cp);
sd = -R*thetad.*st -L*phid.*sp;

thetadd = zeros( size( theta ) );
phidd = ( R*thetadd.*ct -R*thetad.*thetad.*st +L*phid.*phid.*sp ) ./ (L*cp);
sdd = -R*thetadd.*st -R*thetad.*thetad.*ct -L*phidd.*sp -L*phid.*phid.*cp;

figure( 1 )
  plot( phi2_deg,x4dd,'go', phi2_deg,sdd,'r' )
  axis( [ 0 360 -250 150 ] )
  title( 'Slider crank C02 - 60 rpm CCW' )
  xlabel( 'Crank angle [deg]' )
  ylabel( 'Piston acceleration [cpss]' )
  legend( 'Haug', 'geometric' )

% bottom - sc_main
```

ME 581 – C02 Name ________________________

```
% sc_ini.m - slider crank for ME 581 extra credit C02
%   initialize constants and assembly guesses
% HJSIII, 20.03.04

% mechanism constants
R_link2 = 4;       % units [cm]
L_link3 = 14.23;

s1pA = [ 0  0 ]';

s2pA = [ 0  0 ]';
s2pB = [ R_link2  0 ]';

s3pB = [ 0  0 ]';
s3pC = [ L_link3  0 ]';

s4pC = [ 0  0 ]';

% initial guesses
phi2 = 0 * d2r;
phi3 = 0 * d2r;
phi4 = 0 *  d2r;

q = zeros(9,1);
q(1) = 0;
q(2) = 0;
q(3) = phi2;

q(4) = R_link2;
q(5) = 0;
q(6) = phi3;

q(7) = R_link2 + L_link3;
q(8) = 0;
q(9) = phi4;

% driver for crank - phi2 = w2*t
w2 = +60 * 2 * pi / 60;   % 60 rpm CCW, convert to rad/sec

% bottom - sc_ini
```

```
% sc_phi.m - slider crank for ME 581 extra credit C02
%   evaluate constraints and Jacobian for crank driving constraint
% HJSIII - 20.03.04

% global location of local frames and rotation matrices
r1 = [ 0  0 ]';
r2 = q(1:2);
r3 = q(4:5);
r4 = q(7:8);
phi1 = 0;
phi2 = q(3);
phi3 = q(6);
phi4 = q(9);
A1 = [ cos(phi1) -sin(phi1); sin(phi1) cos(phi1) ];
A2 = [ cos(phi2) -sin(phi2); sin(phi2) cos(phi2) ];
A3 = [ cos(phi3) -sin(phi3); sin(phi3) cos(phi3) ];
A4 = [ cos(phi4) -sin(phi4); sin(phi4) cos(phi4) ];
B2 = A2 * R;
B3 = A3 * R;
B4 = A4 * R;

% global locations of points
r1A = r1 + A1*s1pA;
r2A = r2 + A2*s2pA;
r2B = r2 + A2*s2pB;
r3B = r3 + A3*s3pB;
r3C = r3 + A3*s3pC;
r4C = r4 + A4*s4pC;
y4 = r4(2);

% three revolute constraints and slider constraint
PHI(1:2,1) = r2A - r1A;
PHI(3:4,1) = r3B - r2B;
PHI(5:6,1) = r4C - r3C;
PHI(7:8,1) = [ y4  phi4 ]';

% crank driver constraint
PHI(9,1) = phi2 - w2*t;

% Jacobian by rows
JAC = zeros(9,9);
JAC(1:2,1:3) = [  eye(2)   B2*s2pA ];

JAC(3:4,1:3) = [ -eye(2)  -B2*s2pB ];
JAC(3:4,4:6) = [  eye(2)   B3*s3pB ];

JAC(5:6,4:6) = [ -eye(2)  -B3*s3pC ];
JAC(5:6,7:9) = [  eye(2)   B4*s4pC ];

JAC(7,8) = 1;
JAC(8,9) = 1;

% driver constraint in Jacobian
JAC(9,3) = 1;

% current results
current_crank = phi2 / d2r;

% bottom - sc_phi
```

ME 581 – C02

Name ________________________

```
% sc_kin.m - slider crank for ME 581 extra credit C02
%   positon, velocity, and acceleration
% HJSIII, 20.03.04

% Newton-Raphson position solution
assy_tol = 1e-5;
sc_phi
while max(abs(PHI)) > assy_tol,
  q = q - inv(JAC) * PHI;
  sc_phi
end

% velocity
velrhs = zeros(9,1);
velrhs(9) = w2;
qd = inv(JAC) * velrhs;

% global velocities of points
r2d = qd(1:2);
r3d = qd(4:5);
r4d = qd(7:8);
phi2d = qd(3);
phi3d = qd(6);
phi4d = qd(9);

% acceleration
accrhs = zeros(9,1);
accrhs(1:2) = A2*s2pA*phi2d*phi2d;
accrhs(3:4) = A3*s3pB*phi3d*phi3d - A2*s2pB*phi2d*phi2d;
accrhs(5:6) = A4*s4pC*phi4d*phi4d - A3*s3pC*phi3d*phi3d;
accrhs(7:8) = [ 0  0 ]';
accrhs(9) = 0;
qdd = inv(JAC) * accrhs;

% global accelerations
r2dd = qdd(1:2);
r3dd = qdd(4:5);
r4dd = qdd(7:8);
phi2dd = qdd(3);
phi3dd = qdd(6);
phi4dd = qdd(9);

% bottom - sc_kin
```