ME 481 - H08 Name ______________________

1) Develop a SolidWorks (SW) kinematic simulation for the four bar shown below with crank link 2 rotating at constant 30 rpm CCW. Attach a screen shot of your mechanism. Create three MATLAB graphs from your results. Be certain to start each plot at $\theta_2 = 0°$. Do not plot $-180° \leq \theta_2 \leq 180°$.

a) θ_4 [deg] as a function of θ_2 [deg] (only one full revolution)

b) $\dot{\theta}_4$ [rad/sec] as a function of θ_2 [deg] (only one full revolution)

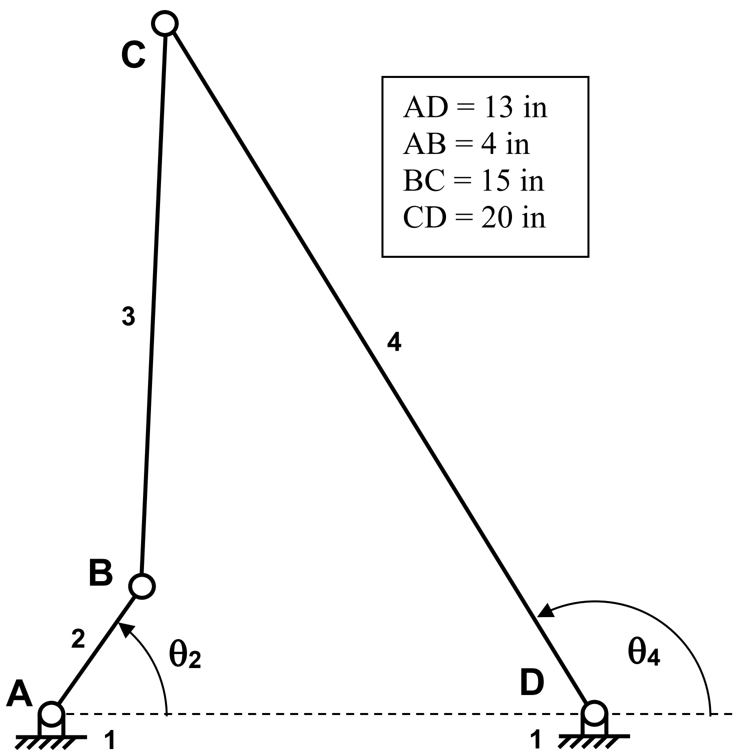
c) $\ddot{\theta}_4$ [rad/sec^2] as a function of θ_2 [deg] (only one full revolution)

2) Use simple trigonometry to determine θ_{4_MAX} and θ_{4_MIN} and compare to SW values. Show your work.

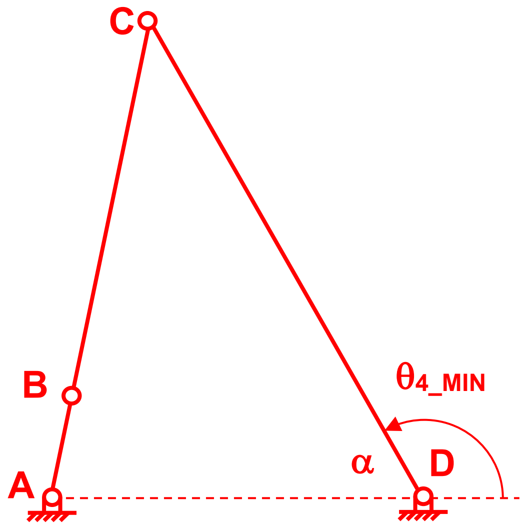
trig θ_{4_MAX} 149.4898° trig θ_{4_MIN} 113.5783°

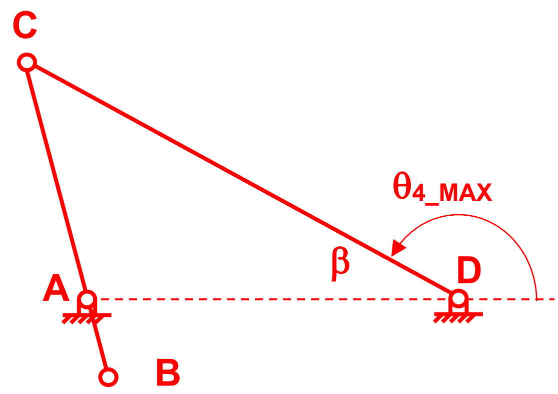
SW θ_{4_MAX} 149.4477° SW θ_{4_MIN} 113.6051°

3) Explicitly verify your SW results and provide documentation including screen plots and hardcopy of code.



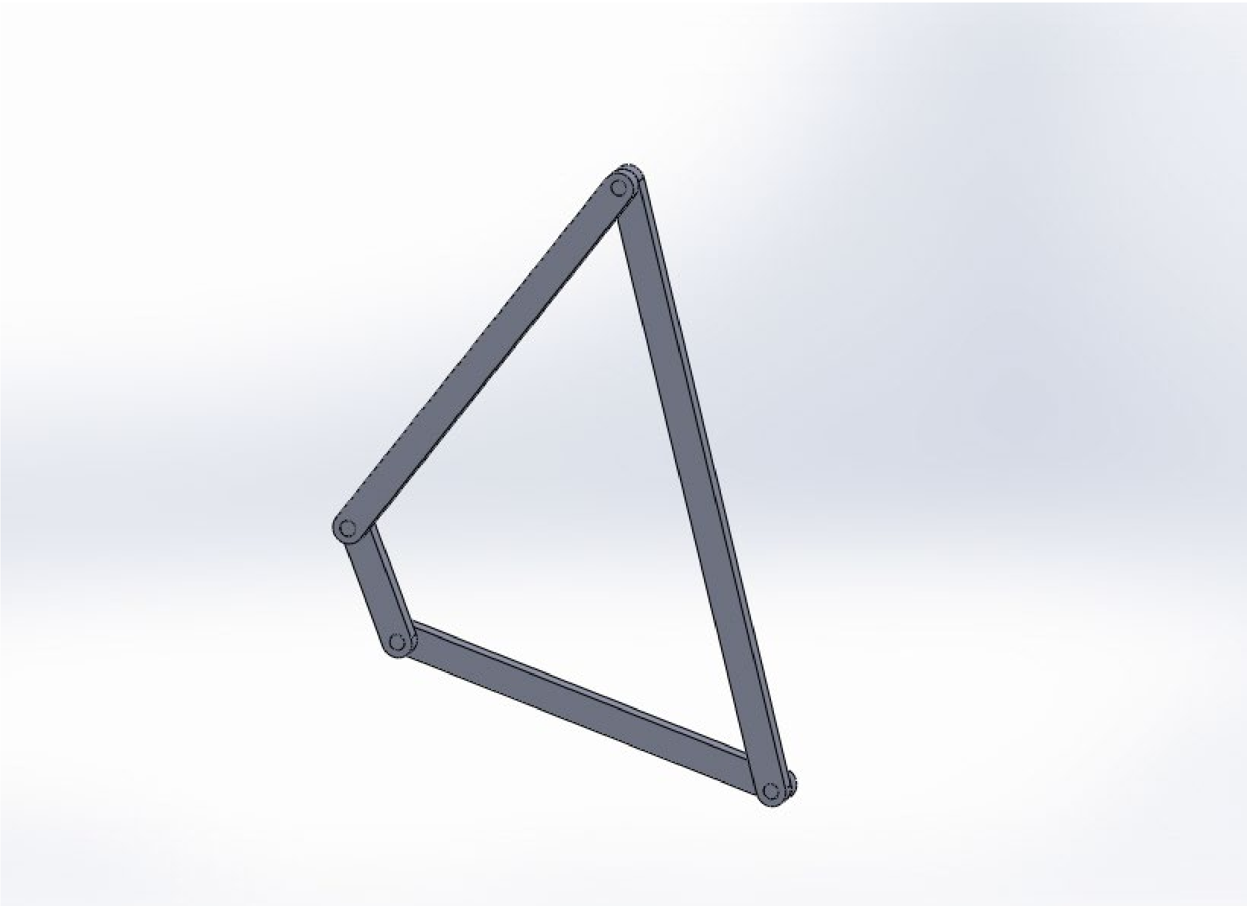
ME 481 - H08 Name ________________________





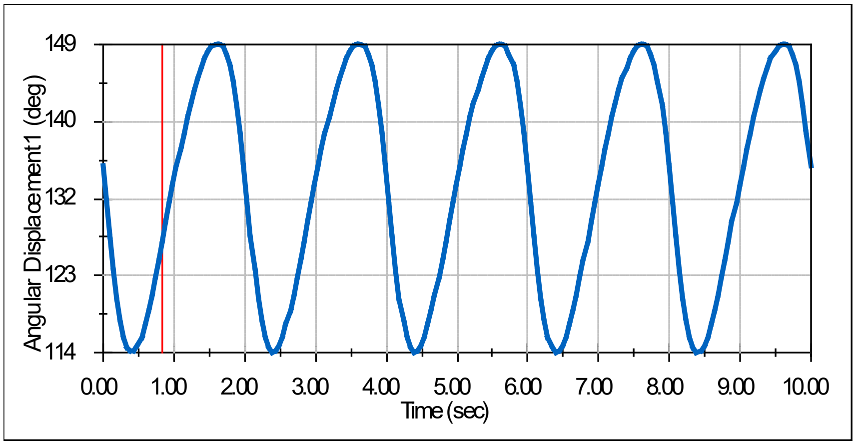
$$(BC+AB)^2 = AD^2 + CD^2 - 2(AD)(CD)\cos\alpha \qquad \alpha = 66.4218° \qquad \theta_{4\_MIN} = 113.5782°$$

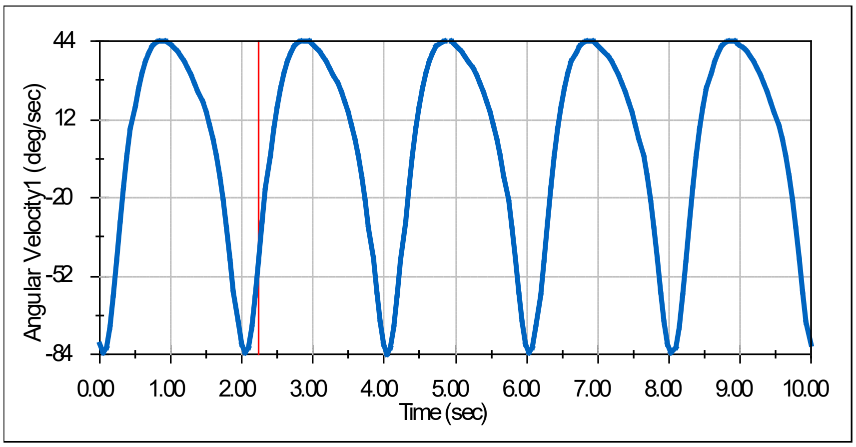
$$(BC-AB)^2 = AD^2 + CD^2 - 2(AD)(CD)\cos\beta \qquad \beta = 30.5102° \qquad \theta_{4\_MAX} = 149.4898°$$

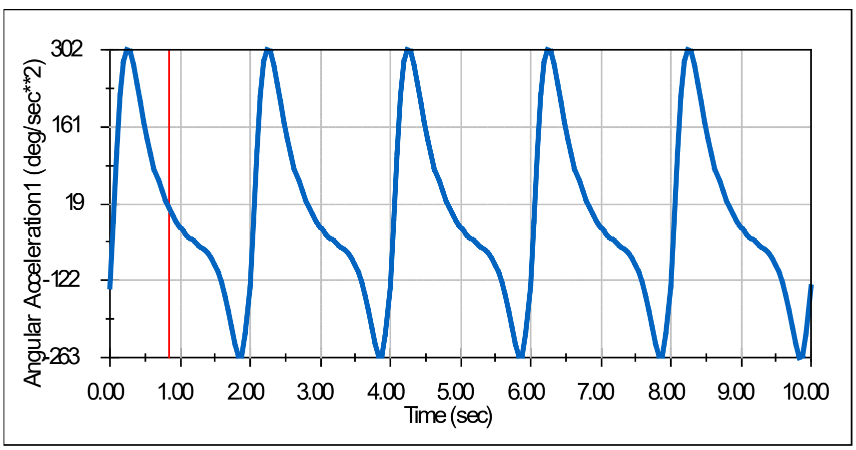


ME 481 - H08 **Name ________________________**

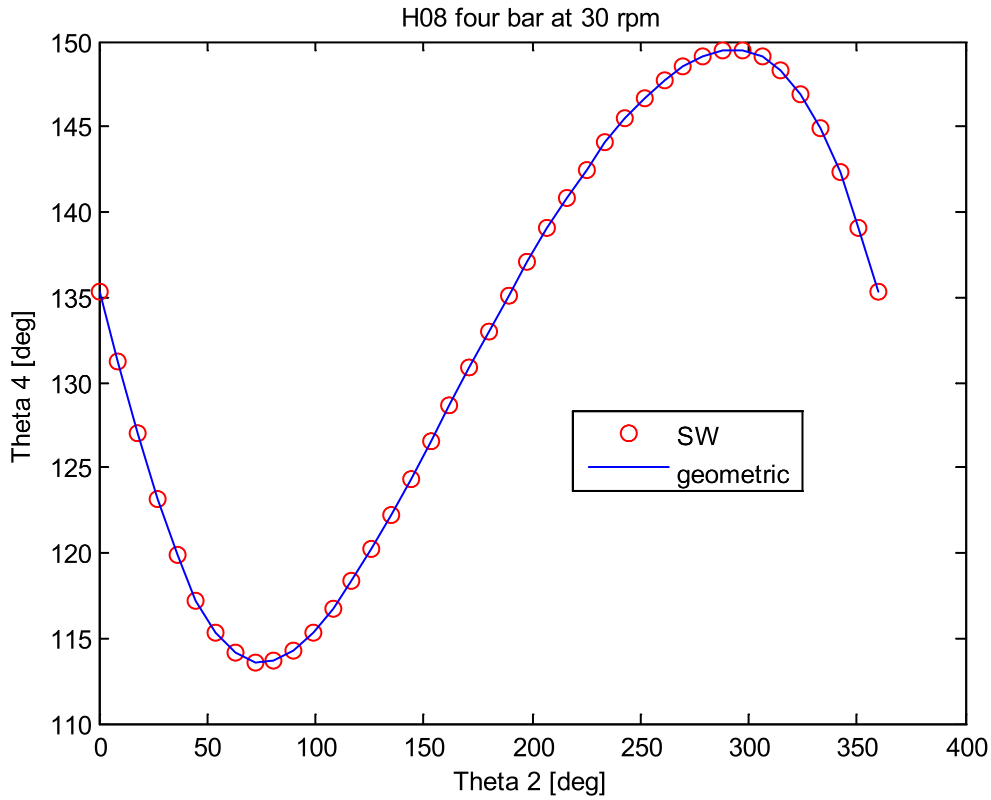
Results directly from SW

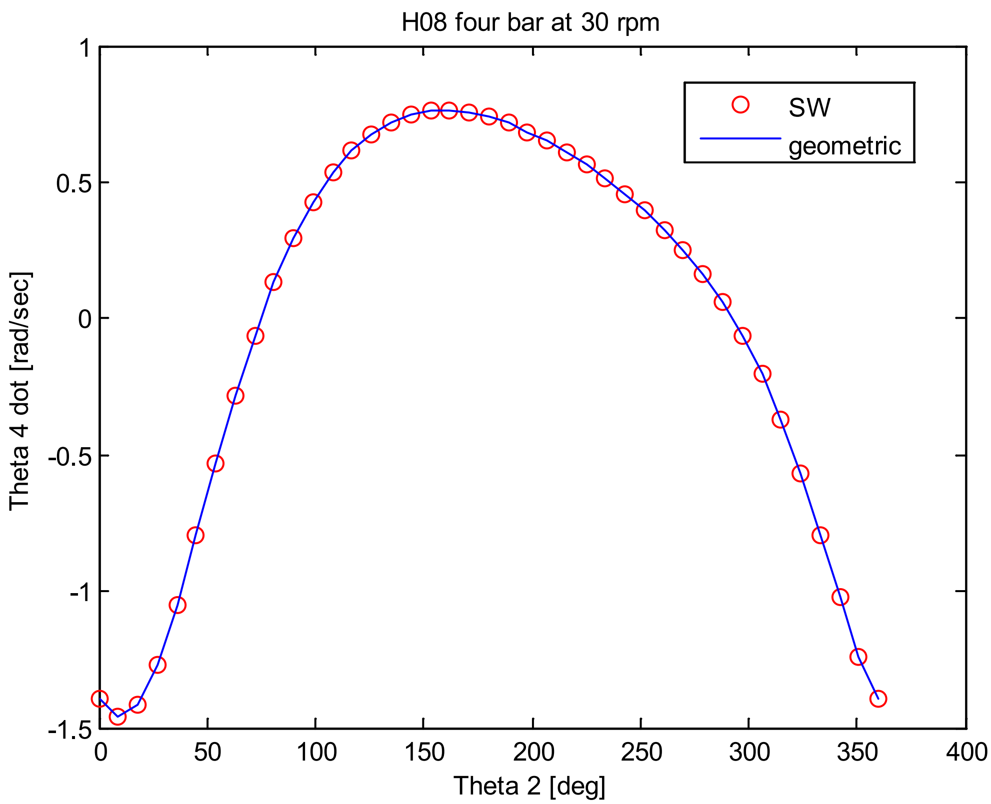


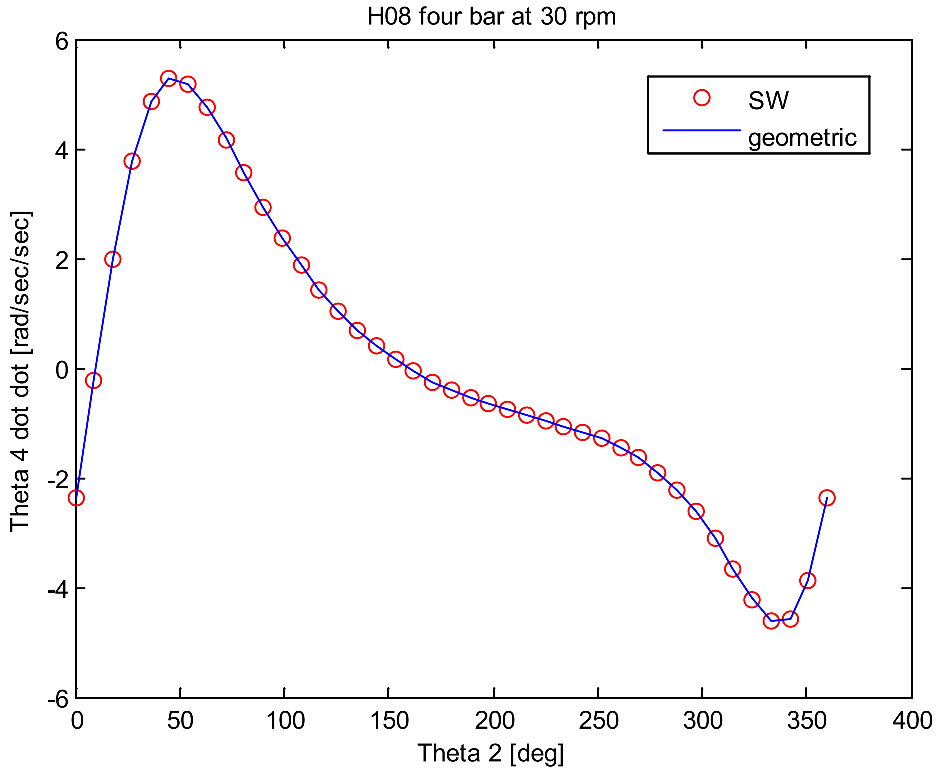


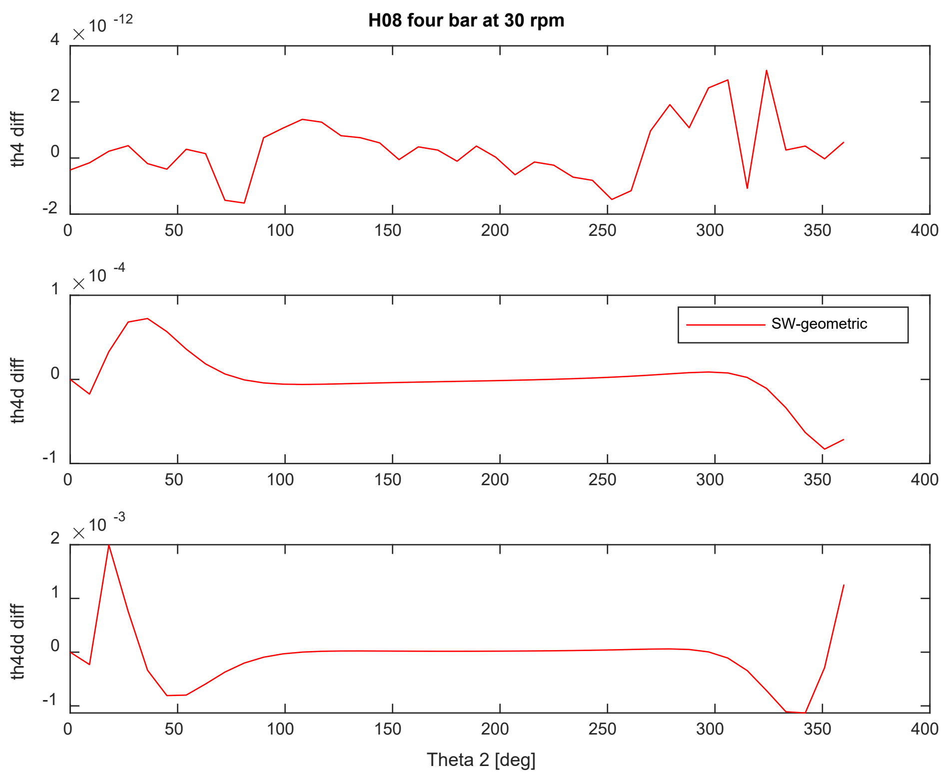


Name ______________________


H08 four bar at 30 rpm
150
145
140
135
130
125
120
115
110
0
50
100
150
200
250
300
350
400
Theta 4 [deg]
Theta 2 [deg]
SW
geometric


H08 four bar at 30 rpm
1
0.5
0
-0.5
-1
-1.5
0
50
100
150
200
250
300
350
400
Theta 4 dot [rad/sec]
Theta 2 [deg]
SW
geometric


H08 four bar at 30 rpm
SW
geometric
Theta 4 dot dot [rad/sec/sec]
Theta 2 [deg]
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400


H08 four bar at 30 rpm
× 10 -12
th4 diff
× 10 -4
th4d diff
SW-geometric
× 10 -3
th4dd diff
Theta 2 [deg]

```
% h08.m - ME 481 homework 8 - plot SW results
% HJSIII, 20.02.24

clear

% general constants
d2r = pi / 180;

% mechanism constants
r1 = 13;  % [inch]
r2 =  4;  % [inch]
r3 = 15;  % [inch]
r4 = 20;  % [inch]
w2 = 30 * 2 * pi / 60;  % 30 rpm convert to [rad/sec]
a2 = 0;                 % constant w2

% read data from CSV files
%   Note 1 - must cut text header first two lines using Notepad, Word, etc
%   Note 2 - SW provides deg, deg/sec and deg/sec/sec
tp = csvread( 'h08_pos_cut.csv' );  % [deg]
tv = csvread( 'h08_vel_cut.csv' );  % [deg/sec]
ta = csvread( 'h08_acc_cut.csv' );  % [deg/sec/sec]

% raw data - one revolution = rows 1 through 41
t = tp(1:41,1);           % [sec]
th2 = t * w2;             % [rad]
th2_deg = th2 / d2r;      % [deg]

th4_deg_SW = tp(1:41,2);        % [deg]
th4d_SW    = tv(1:41,2) * d2r;  % [rad/sec]
th4dd_SW   = ta(1:41,2) * d2r;  % [rad/sec/sec]

% geometric position equations
e = sqrt( r1*r1 + r2*r2 - 2*r1*r2*cos(th2) );
alpha = asin( r2 * sin(th2) ./ e );
gamma = acos( ( r3*r3 + r4*r4 - e.*e ) /2 /r3 /r4 );
beta = asin( r3 * sin(gamma) ./ e );
th4 = pi - alpha - beta;
th4_deg = th4 / d2r;

% geometric velocity solutions
th2d = w2;
ed = r1*r2*th2d*sin(th2) ./ e;
ad = ( r2*th2d*cos(th2) - ed.*sin(alpha) ) ./e ./cos(alpha);
gd = e.*ed /r3 /r4 ./sin(gamma);
bd = ( r3*gd.*cos(gamma) - ed.*sin(beta) ) ./e ./ cos(beta);
th4d = -ad - bd;

% geometric acceleration solutions
th2dd = a2;
edd = ( r1*r2*(th2d*th2d*cos(th2) + th2dd*sin(th2)) - ed.*ed ) ./ e;
add = ( -r2*th2d*th2d*sin(th2) +r2*th2dd*cos(th2) - edd.*sin(alpha) ...
        -2*ed.*ad.*cos(alpha) + e.*ad.*ad.*sin(alpha) ) ./e ./cos(alpha);
gdd = ( ed.*ed +e.*edd - r3*r4*gd.*gd.*cos(gamma) ) /r3 /r4 ./sin(gamma);
bdd = ( -r3*gd.*gd.*sin(gamma) +r3*gdd.*cos(gamma) -edd.*sin(beta) ...
        -2*ed.*bd.*cos(beta) +e.*bd.*bd.*sin(beta) ) ./e ./cos(beta);
th4dd = -add - bdd;

figure( 1 )
  clf
  plot( th2_deg,th4_deg_SW,'ro', th2_deg,th4_deg,'b' )
  xlabel( 'Theta 2 [deg]' )
  ylabel( 'Theta 4 [deg]' )
  legend( 'SW', 'geometric' )
  title( 'H08 four bar at 30 rpm' )

figure( 2 )
  clf
  plot( th2_deg,th4d_SW,'ro', th2_deg,th4d,'b' )
  xlabel( 'Theta 2 [deg]' )
  ylabel( 'Theta 4 dot [rad/sec]' )
```

```
  legend( 'SW', 'geometric' )
  title( 'H08 four bar at 30 rpm' )

figure( 3 )
  clf
  plot( th2_deg,th4dd_SW,'ro', th2_deg,th4dd,'b' )
  xlabel( 'Theta 2 [deg]' )
  ylabel( 'Theta 4 dot dot [rad/sec/sec]' )
  legend( 'SW', 'geometric' )
  title( 'H08 four bar at 30 rpm' )

figure( 4 )
  clf
  subplot( 3, 1, 1 )
    plot( th2_deg, th4_deg_SW-th4_deg, 'r' )
    ylabel( 'th4 diff' )
    title( 'H08 four bar at 30 rpm' )
  subplot( 3, 1, 2 )
    plot( th2_deg, th4d_SW-th4d, 'r' )
    ylabel( 'th4d diff' )
    legend( 'SW-geometric' )
subplot( 3, 1, 3 )
    plot( th2_deg, th4dd_SW-th4dd, 'r' )
    ylabel( 'th4dd diff' )
    xlabel( 'Theta 2 [deg]' )

% bottom - h08
```