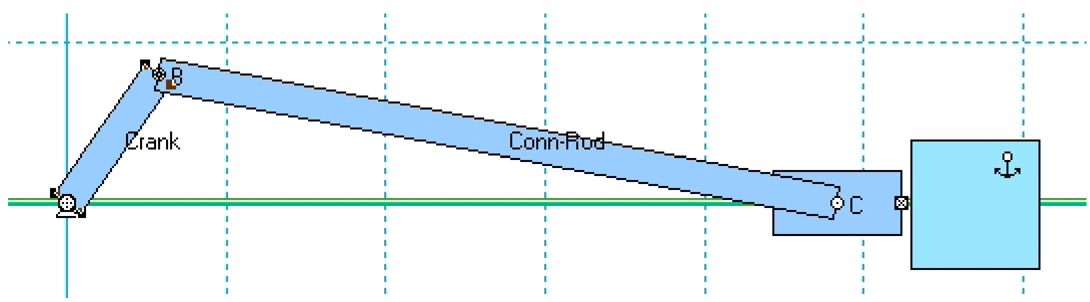
ME 481 – H09 Name ________________________

1) Modify your Working Model (WM) slider crank simulation as detailed below.
   a) Change the motor that drives the crank to apply constant torque of 20 ft-lbf.
   b) Place a large block so that the piston cannot move all the way to TDC.
   c) Select World then Accuracy and set Animation Step to 0.0001 sec. You may also need to select World then Accuracy then More Choices and set Overlap Error smaller.
   d) Left-click on the piston to highlight it. Hold down the Shift Key and left-click on the block to highlight it also. Select Object then Collide to enable collision between the two objects. Select Measure then Contact Force to measure piston force.
   e) Move the block to three different positions and record piston force in the table below.
   f) Validate your simulation with the closed-form force-torque equation derived in class.
   g) Attach a screen shot of your WM mechanism.

Crank angle [deg]	Conn-rod angle [deg]	Crank torque [in.lbf]	WM piston force [lbf]	Equation piston force [lbf]
31.373	6.812	240	391.410	391.3519
85.882	13.118	240	240.255	240.2545
130.766	9.921	240	378.828	378.8317

$$T_{12} = \frac{P\ R\ \sin(\theta+\phi)}{\cos\phi} \qquad P = \frac{T_{12}\cos\phi}{R\ \sin(\theta+\phi)}$$

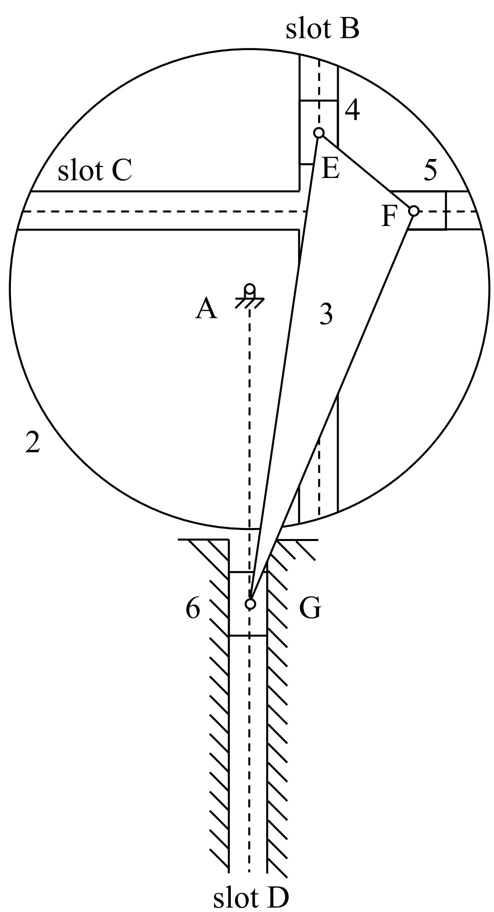
EXTRA CREDIT
Develop a WM simulation to slowly move the block back and forth. Export WM data and read into MATLAB. Provide validation plots of WM piston force and closed-form equation piston force on the same MATLAB graph as a function of crank angle. Attach a screen shot of your WM mechanism.



ME 481 – H09 **Name ________________________**

2) Determine motor torque T_{12} required to push needle link 6 down with 0.5 N at the position shown below. The mechanism is drawn to scale full size. Neglect friction and dynamic effects. Show your work.

T_{12} 7.36 N.mm CW instant centers
7.69 N.mm CW WM
7.603 N.mm CW Newtonian

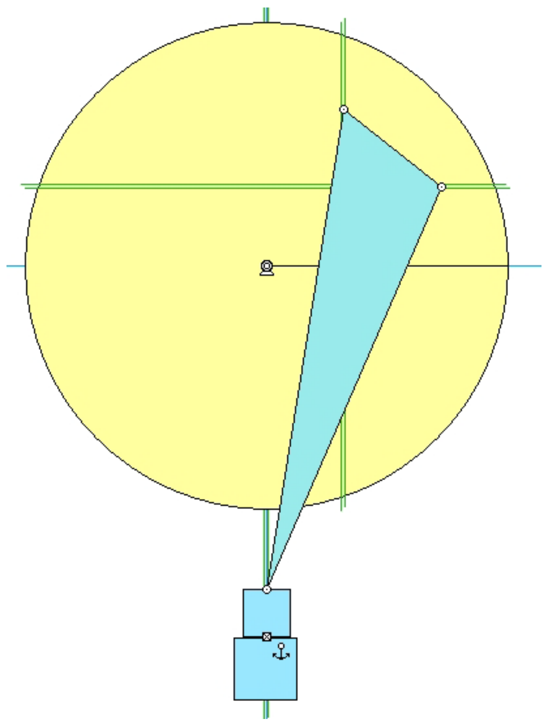


from H05
ω_2 = 4 rev/sec = 8 π rad/sec

actual power
$T_{12} \circ \omega_2 + F_{NEEDLE} \circ V_{G6} = 0$

graphical instant centers
V_{G6} = 370 mmps down
T_{12} = 7.36 N.mm CW

ME 481 – H09 **Name** ________________________



Working Model - gravity OFF

T_{12} = -7690 N.mm, F_{NEEDLE} = 499.98 N

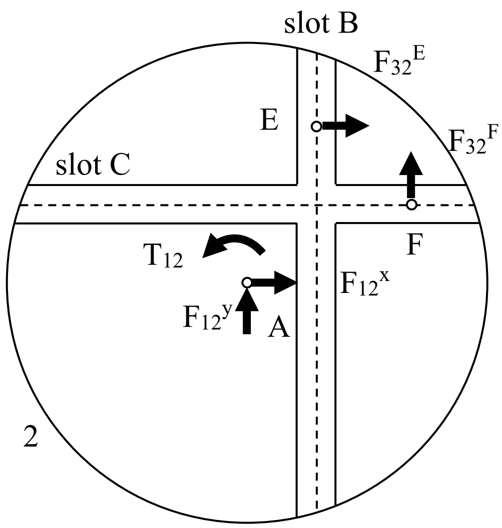
T_{12} = -769 N.mm, F_{NEEDLE} = 50.0 N

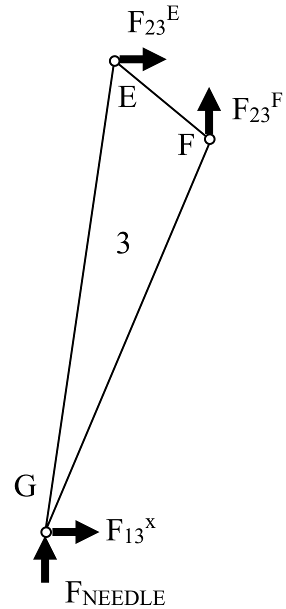
T_{12} = -76.9 N.mm, F_{NEEDLE} = 5.00 N

T_{12} = -7.69 N.mm, F_{NEEDLE} = 0.50 N

ME 481 – H09 **Name ________________________**

remove each slider and replace with pin-in-slot   assume no friction





ΣF on 2 right + $+F_{12}^x + F_{32}^E = 0$

ΣF on 2 up + $+F_{12}^y + F_{32}^F = 0$

ΣM on 2 about A CCW + $-F_{32}^E\ AE^y + F_{32}^F\ AF^x + T_{12} = 0$

ΣF on 3 right + $+F_{23}^E + F_{13}^x = 0$

ΣF on 3 up + $+F_{23}^F + F_{NEEDLE} = 0$

ΣM on 3 about G CCW + $-F_{23}^E\ GE^y + F_{23}^F\ GF^x = 0$

using graphical measurements from drawing

$AE^y = 20.6$ mm $AF^x = GF^x = 21.1$ mm $GE^y = 62.3$ mm

$F_{NEEDLE} = 0.5$ N

from **ΣF on 3 y** $F_{23}^F = -0.5$ N $F_{32}^F = +0.5$ N

from **ΣM on 3** $F_{23}^E = -0.169$ N $F_{32}^E = +0.169$ N

from **ΣM on 2** $T_{12} = -7.068$ N.mm

using exact measurements computed in H05

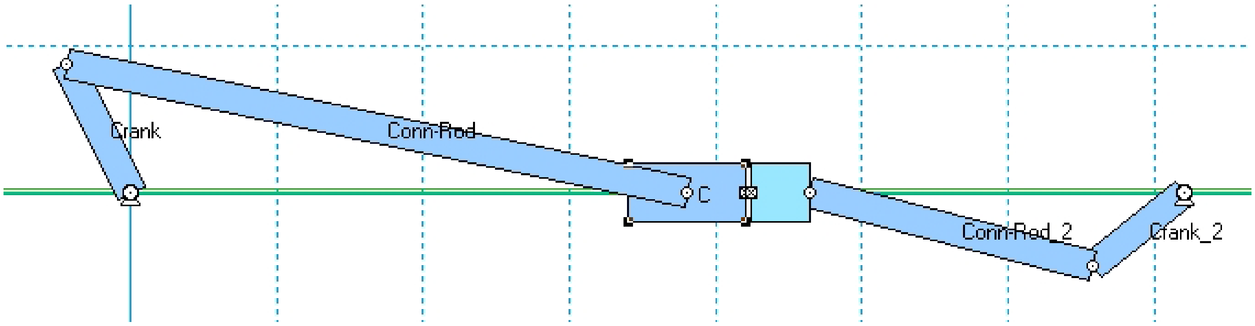
$$\{r\}^E = \begin{Bmatrix} 10 \\ 19.9279 \end{Bmatrix} \qquad \{r\}^F = \begin{Bmatrix} 22.5473 \\ 10 \end{Bmatrix} \qquad \{r\}^G = \begin{Bmatrix} 0 \\ -41.2603 \end{Bmatrix}$$

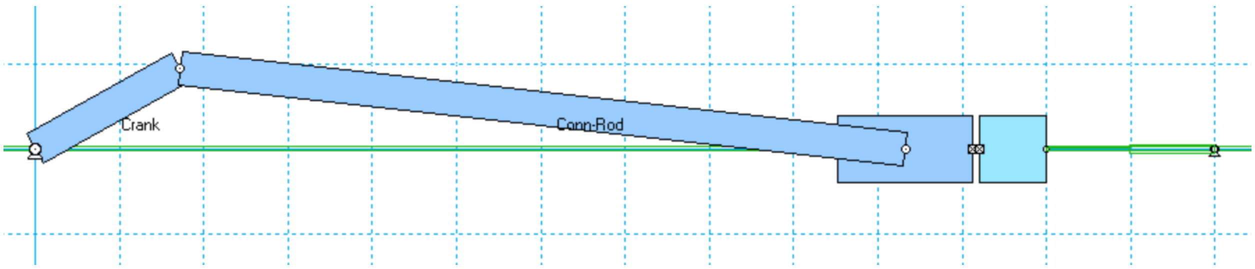
$AE^y = 19.9279$ mm $AF^x = GF^x = 22.5473$ mm $GE^y = 61.1882$ mm

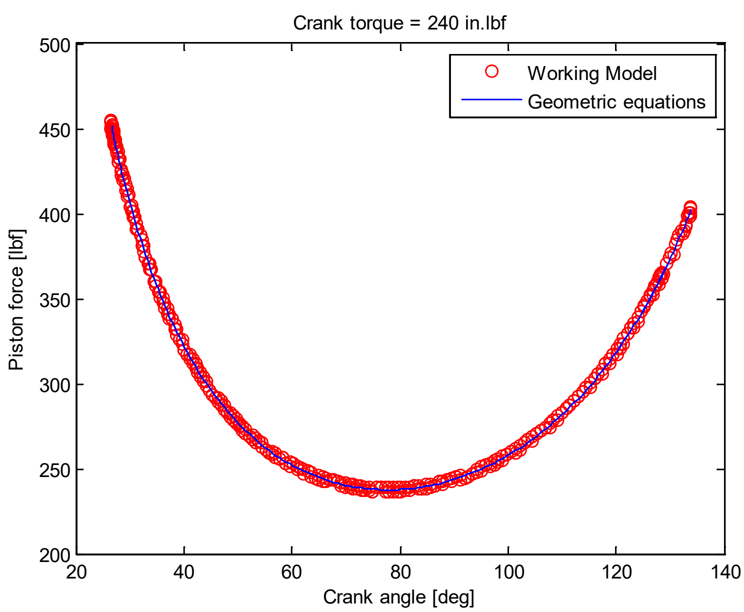
from **ΣM on 3** $F_{23}^E = -0.1842$ N $F_{32}^E = +0.1842$ N

from **ΣM on 2** $T_{12} = -7.6029$ N.mm

ME 481 – H09 **Name ______________________**







```
% h09_ec.m - ME 481 H09 - read WM data for slider crank and validate
% HJSIII, 11.03.14

% general constants
d2r = pi / 180;

% mechanism constants
R = 1.97 / 2;          % crank length [inch]
L = 4.33;              % conn-rod length [inch]
T12 = 240;             % crank torque [in.lbf]

% load WM data - note angles in degrees
load hw09_ec_cut.txt;

t = hw09_ec_cut(:,1);
th_deg = hw09_ec_cut(:,2);
phi_deg = -hw09_ec_cut(:,4);
P_WM = -hw09_ec_cut(:,6);

% crank information
th = th_deg * d2r;

% geometric equations
phi = asin(  R*sin(th) / L );
P_geo = T12 * cos(phi) /R ./sin(th+phi);

% plot results
figure( 1 )
  plot( th_deg,P_WM,'ro', th_deg,P_geo,'b' )
%  axis( [ 0 360  0 6 ] )
  xlabel( 'Crank angle [deg]' )
  ylabel( 'Piston force [lbf]' )
  legend( 'Working Model', 'Geometric equations' )
  title( 'Crank torque = 240 in.lbf' )

% manual check
th_deg_manual  = [ 31.373  85.882  130.766 ];
phi_deg_manual = [  6.812  13.118    9.921 ];
th = th_deg_manual * d2r;
phi = phi_deg_manual * d2r;
P_manual = T12 * cos(phi) /R ./sin(th+phi)

% bottom of hw09_ec.m
```