Matlab Scripts Exported to PDF
From ME213 Machine Dynamics directory.
David Malawey 2025.05

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Matlab scripts can be recreated by directly copying lines of code from the PDF here and insertion into a text file, then renaming with "FILENAME.m" file extension. Files are originally pure text files but colors are assigned by notepad upon export to PDF, with default code detection settings enabled.

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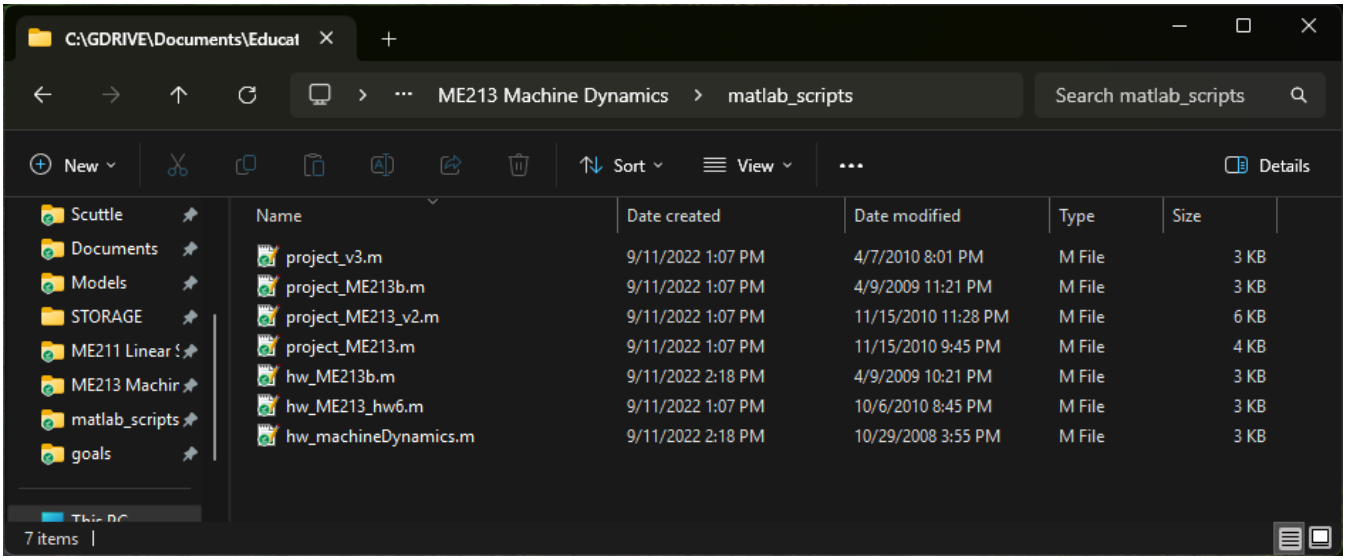

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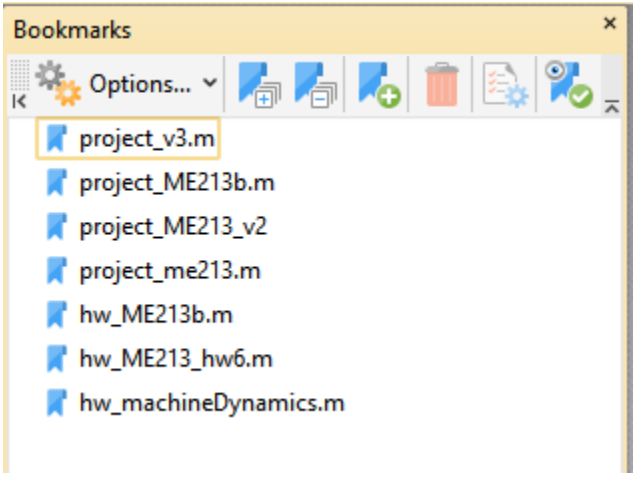

```
format short e;
R1=1;
R2=2.17;
R3=2.067;
R4=2.310;
R5=5.4;
theta2=[0:pi/360:2*pi];
omega2=zeros(size(theta2));
theta3=zeros(size(theta2));
theta4=zeros(size(theta2));
th4=zeros(size(theta2));
omega3=zeros(size(theta2));
omega4=zeros(size(theta2));
omega5=zeros(size(theta2));
alpha3=zeros(size(theta2));
alpha4=zeros(size(theta2));
alpha6=zeros(size(theta2));
alpha2=0;
n=max(size(theta2));
for j=1:n;
    omega2(j)=sqrt(4+2*alpha2*theta2(j));
end
for k=1:n;
    K1=R1/R2;
    K2=R1/R4;
    K3=(R1^2+R2^2+R4^2-R3^2)/(2*R2*R4);
    K4=R1/R3;
    K5=(R4^2-R1^2-R2^2-R3^2)/(2*R2*R3);
    D=(1+K4)*cos(theta2(k))+K5-K1;
    F=(K4-1)*cos(theta2(k))+K5+K1;
    A=cos(theta2(k))-K1-K2*cos(theta2(k))+K3;
    B=-2*sin(theta2(k));
    C=K1-(K2+1)*cos(theta2(k))+K3;
    z1=(-B+sqrt(B^2-4*A*C))/(2*A);
    w1=(-B+sqrt(B^2-4*D*F))/(2*D);
    L1=2*z1/(1+z1^2);
    M1=(1-z1^2)/(1+z1^2);
    N1=2*w1/(1+w1^2);
    P1=(1-w1^2)/(1+w1^2);
    theta4(k)=atan2(L1,M1);
    theta3(k)=atan2(N1,P1);

end
for k=1:n;
    Q=[R3*cos(theta3(k)) -R4*cos(theta4(k));R3*sin(theta3(k)) -R4*sin(theta4(k))];
    h=[-R2*omega2(k)*cos(theta2(k));-R2*omega2(k)*sin(theta2(k))];
    z=inv(Q)*h;
    omega3(k)=z(1);
    omega4(k)=z(2);
    p1=[-R2*alpha2*cos(theta2(k));-R2*alpha2*sin(theta2(k))];
    p2=[R2*omega2(k)^2*sin(theta2(k));-R2*omega2(k)^2*cos(theta2(k))];
    p3=[R3*omega3(k)^2*sin(theta3(k));-R3*omega3(k)^2*cos(theta3(k))];
    p4=[-R4*omega4(k)^2*sin(theta4(k));R4*omega4(k)^2*cos(theta4(k))];
    f=p1+p2+p3+p4;
    l=inv(Q)*f;
    alpha3(k)=l(1);
    alpha4(k)=l(2);
end

for p=1:n;
    th4(p)=theta4(p)-(102/180)*pi;
end

Vc=zeros(size(theta2));
theta5=zeros(size(theta2));
Dist=zeros(size(theta2));
Ac=zeros(size(theta2));
alpha5=zeros(size(theta2));
for k=1:n;
```

```
    T=sqrt(R5^2-R4^2*(sin(th4(k))^2));
    theta5(k)=atan2(R4*sin(th4(k)),-T);
end
Vcdeg=zeros(size(theta2));
for k=1:n;
    Q=[R5*sin(theta5(k)) -1;-R5*cos(theta5(k)) +0];
    h=[R4*omega4*sin(th4(k));-R4*omega4*sin(th4(k))];
    z=inv(Q)*h;
    omega5(k)=z(1);
    Vc(k)=z(2);
    p1=[R4*alpha4(k)*sin(th4(k));R4*omega4(k)^2*cos(th4(k))];
    p2=[R4*omega4(k)^2*cos(th4(k));-R4*alpha4(k)*cos(th4(k))];
    p3=[-R5*omega5(k)^2*cos(theta5(k));-R5*omega5(k)^2*sin(theta5(k))];
    f=p1+p2+p3;
    l=inv(Q)*f;
    alpha5(k)=l(1);
    Ac(k)=l(2);
end



%plot(theta2,Vc,'-',theta2,Ac,'-',theta2,omega4,'-',theta2,alpha4,'-');
%plot(theta2,Vc);
%xlabel('Theta 2');
%ylabel('Velocity');
%title('Velocity vs. Theta 2');
%plot(theta2,Ac);
%xlabel('Theta 2');
%ylabel('Acceleration');
%title('Acceleration vs. Theta 2');
%plot(theta2,omega4);
%xlabel('Theta 2');
%ylabel('Omega 4');
%title('Omega 4 vs. Theta 2');
plot(theta2,alpha4);
xlabel('Theta 2');
ylabel('Alpha 4');
title('Alpha 4 vs. Theta 2');
```

```
format short e;
J=zeros(2,2);

d=7.487;
a=9.174;
b=12.971;
c=9.573;
p=15;
MINVAL = -26;
MAXVAL = -20.55;
delta = 0.25;

Maxits=500;
Tol=1.0e-6;

X=[4;2];

for i=MINVAL:delta:MAXVAL;

    theta2=i*(pi/180);

for i=1:Maxits;
    theta3=X(1);
    theta4=X(2);

    F1=a*cos(theta2)+b*cos(theta3)-c*cos(theta4)-d;
    F2=a*sin(theta2)+b*sin(theta3)-c*sin(theta4);

    J(1,1)=-b*sin(theta3);
    J(1,2)=c*sin(theta4);
    J(2,1)=b*cos(theta3);
    J(2,2)=-c*cos(theta4);

    deltaX=inv(J)*[-F1;-F2];
    X=X+deltaX;

    theta3=X(1);
    theta4=X(2);

    F1check=abs(a*cos(theta2)+b*cos(theta3)-c*cos(theta4)-d);
    F2check=abs(a*sin(theta2)+b*sin(theta3)-c*sin(theta4));

    Fmax=max([F1check,F2check]);
    if Fmax<Tol
        break
    end
end

if i<Maxits
    fprintf('\n')
    fprintf('********** Newton Raphson Method **********\n\n');
    fprintf('Position Analysis:\n');
    fprintf('Inputs:\n');
    fprintf('a = %-2g mm  b = %-2g mm  c = %-2g mm  d = %-2g mm  theta2 = %-2.2f degrees'
    ,a,b,c,d,theta2*180/pi');
    fprintf('\nIterations=%-5g\n',i);
    fprintf('Outputs:\n');
    fprintf('theta3 = %-6.2f degrees',X(1)*180/pi);
    fprintf('  theta4 = %-6.2f degrees\n',X(2)*180/pi);
else
    fprintf('we did not converge!\n');
end

theta3=X(1);
theta4=X(2);
w2=2;

w3 = (a*sin(theta4 - theta2))/(b*sin(theta3-theta4))*w2;
w4 = (a*sin(theta2 - theta3))/(c*sin(theta4-theta3))*w2;
```

```
69
70  fprintf('\nVelocity Analysis:\n');
71  fprintf('Inputs:\n');
72  fprintf('w2 = %-2g rad/s\n',w2);
73  fprintf('Outputs:\n');
74  fprintf('w3 = %-6.2f rad/s',w3);
75  fprintf('  w4 = %-6.2f rad/s\n',w4);
76
77  A = c*sin(theta4);
78  B = b*sin(theta3);
79  C = a*(w2^2)*cos(theta2)+b*(w3^2)*cos(theta3)-c*(w4^2)*cos(theta4);
80  D = c*cos(theta4);
81  E = b*cos(theta3);
82  F = -a*(w2^2)*sin(theta2)-b*(w3^2)*sin(theta3)+c*(w4^2)*sin(theta4);
83
84  a3 = (C*D-A*F)/(A*E-B*D);
85  a4 = (C*E-B*F)/(A*E-B*D);
86
87  Vax = a*w2*-sin(theta2);
88  Vpax = p*w3*-sin(theta3);
89
90  Vay = a*w2*cos(theta2);
91  Vpay = p*w3*cos(theta3);
92
93  Vpx = Vax+Vpax;
94  Vpy = Vay+Vpay;
95
96  Vp = sqrt(Vpx^2+Vpy^2);
97
98  Aax = -a*w2^2*cos(theta2);
99  Apax = p*a3*-sin(theta3)-p*w3^2*cos(theta3);
100
101 Aay = -a*w2^2*sin(theta2);
102 Apay = p*a3*cos(theta3)-p*w3^2*sin(theta3);
103
104 Apx = Aax+Apax;
105 Apy = Aay+Apay;
106
107 Ap = sqrt(Apx^2+Apy^2);
108
109 fprintf('\nAcceleration Analysis:');
110 fprintf('\nOutputs:\n');
111 fprintf('a3 = %-6.2f rad/s^2',a3);
112 fprintf('  a4 = %-6.2f rad/s^2\n\n',a4);
113 fprintf('Vp = %-6.2f in/s\n',Vp);
114 fprintf('Ap = %-6.2f in/s\n',Ap);
115
116 end
117
```

```
format long e;
R1=2.22;
R2=1;
R3=2.067;
R4=2.33;
FPX=0;
FPY=-100;
M2=9.75;
M3=113.6331;
M4=22.7175;
IG2=.8145;
IG3=51.7916;
IG4=10.2823;
T4=0;


TH2=0:0.001:2*pi;
TH3=zeros(size(TH2));
TH4=zeros(size(TH2));
TH31=zeros(size(TH2));
TH41=zeros(size(TH2));
TH32=zeros(size(TH2));
TH42=zeros(size(TH2));
OM2=zeros(size(TH2));
OM3=zeros(size(TH2));
OM4=zeros(size(TH2));
AL3=zeros(size(TH2));
AL4=zeros(size(TH2));

A=zeros(2,2);
g=zeros(2,1);
q=zeros(2,1);
B=zeros(9,9);
H=zeros(9,1);
psi=(31-12.401)*(pi/180);
d=(1.6470);

RPX=zeros(size(TH2));
RPY=zeros(size(TH2));


R12X=zeros(size(TH2));
R12Y=zeros(size(TH2));
R32X=zeros(size(TH2));
R32Y=zeros(size(TH2));
R23X=zeros(size(TH2));
R23Y=zeros(size(TH2));
R43X=zeros(size(TH2));
R43Y=zeros(size(TH2));
R34X=zeros(size(TH2));
R34Y=zeros(size(TH2));
R14X=zeros(size(TH2));
R14Y=zeros(size(TH2));

F12X=zeros(size(TH2));
F12Y=zeros(size(TH2));
F32X=zeros(size(TH2));
F32Y=zeros(size(TH2));
F43X=zeros(size(TH2));
F43Y=zeros(size(TH2));
F14X=zeros(size(TH2));
F14Y=zeros(size(TH2));
T12=zeros(size(TH2));

AG2X=zeros(size(TH2));
AG2Y=zeros(size(TH2));
AG3X=zeros(size(TH2));
AG3Y=zeros(size(TH2));
AG4X=zeros(size(TH2));
```

```
AG4Y=zeros(size(TH2));


n=max(size(TH2));

for k=1:n;
        theta2=TH2(k);
    K1=R1/R2;
    K2=R1/R4;
    K3=(R1^2+R2^2+R4^2-R3^2)/(2*R2*R4);
    K4=R1/R3;
    K5=(R4^2-R1^2-R2^2-R3^2)/(2*R2*R3);
    D=(1+K4)*cos(theta2)+K5-K1;
    F=(K4-1)*cos(theta2)+K5+K1;
    A=cos(theta2)-K1-K2*cos(theta2)+K3;
    B=-2*sin(theta2);
    C=K1-(K2+1)*cos(theta2)+K3;
    z1=(-B+sqrt(B^2-4*A*C))/(2*A);
    z2=(-B-sqrt(B^2-4*A*C))/(2*A);
    w1=(-B+sqrt(B^2-4*D*F))/(2*D);
    w2=(-B-sqrt(B^2-4*D*F))/(2*D);
    L1=2*z1/(1+z1^2);
    M1=(1-z1^2)/(1+z1^2);
    L2=2*z2/(1+z2^2);
    M2=(1-z2^2)/(1+z2^2);
    N1=2*w1/(1+w1^2);
    P1=(1-w1^2)/(1+w1^2);
    N2=2*w2/(1+w2^2);
    P2=(1-w2^2)/(1+w2^2);
    TH41(k)=atan2(L1,M1);
    TH42(k)=atan2(L2,M2);
    TH31(k)=atan2(N1,P1);
    TH32(k)=atan2(N2,P2);
end

OM2(1)=40;
AL2=-2;

for k=2:n;
    OM2(k)=sqrt(OM2(1)^2+2*AL2*TH2(k));
end

for k=1:n;
    TH3(k)=TH32(k);
    TH4(k)=TH42(k);
end
for k=1:n;
    A(1,1)=R2*cos(TH3(k));
    A(1,2)=-R4*cos(TH4(k));
    A(2,1)=R3*sin(TH3(k));
    A(2,2)=-R4*sin(TH4(k));
    g(1)= -R2*OM2(k)*cos(TH2(k));
    g(2)= -R2*OM2(k)*sin(TH2(k));
    h=A\g;
    OM3(k)=h(1);
    OM4(k)=h(2);
    q(1)=-R2*AL2*cos(TH2(k))+R2*OM2(k)^2*sin(TH2(k))+R3*OM3(k)^2*sin(TH3(k))-R4*OM4(k)^2*
    sin(TH4(k));
    q(2)=-R2*AL2*sin(TH2(k))-R2*OM2(k)^2*cos(TH2(k))-R3*OM3(k)^2*cos(TH3(k))+R4*OM4(k)^2*
    cos(TH4(k));
    p=A\q;

    AL3(k)=p(1);
    AL4(k)=p(2);

    R12X(k)=-R2*cos(TH2(k))/2;
    R12Y(k)=-R2*sin(TH2(k))/2;
    R32X(k)=-R12X(k);
    R32Y(k)=-R12Y(k);
```

```
137         R23X(k)=-d*cos(TH3(k)-psi);
138         R23Y(k)=-d*sin(TH3(k)-psi);
139         R43X(k)=R3*cos(TH3(k))+R23X(k);
140         R43Y(k)=R3*sin(TH3(k))+R23Y(k);
141         R34X(k)=.5*R4*cos(TH4(k));
142         R34Y(k)=.5*R4*sin(TH4(k));
143         R14X(k)=-R34X(k);
144         R14Y(k)=-R34Y(k);
145
146         AG2X(k)=AL2*R12Y(k)+OM2(k)^2*R12X(k);
147         AG2Y(k)=AL2*R12X(k)+OM2(k)^2*R12Y(k);
148
149         AG3X(k)=AL2*-(R32Y(k)-R12Y(k))-OM2(k)^2*(R32X(k)-R12X(k))-AL3(k)*-R23Y(k)+OM3(k)^2*
            R23X(k);
150         AG3Y(k)=AL2*(R32X(k)-R12X(k))-OM2(k)^2*(R32Y(k)-R12Y(k))-AL3(k)*R23X(k)+OM3(k)^2*R23Y
            (k);
151         AG4X(k)=AL4(k)*R14Y(k)+OM4(k)^2*R14X(k);
152         AG4Y(k)=-AL4(k)*R14X(k)+OM4(k)^2*R14Y(k);
153
154         RPX(k)=3.06*cos(TH3(k)-psi)-R23X(k);
155         RPY(k)=3.06*sin(TH3(k)-psi)-R23Y(k);
156
157
158         B(1,1)=(1);
159         B(1,2)=(0);
160         B(1,3)=(1);
161         B(1,4)=(0);
162         B(1,5)=(0);
163         B(1,6)=(0);
164         B(1,7)=(0);
165         B(1,8)=(0);
166         B(1,9)=(0);
167         B(2,1)=(0);
168         B(2,2)=(1);
169         B(2,3)=(0);
170         B(2,4)=(1);
171         B(2,5)=(0);
172         B(2,6)=(0);
173         B(2,7)=(0);
174         B(2,8)=(0);
175         B(2,9)=(0);
176         B(3,1)=(-R12Y(k));
177         B(3,2)=(R12X(k));
178         B(3,3)=(-R32Y(k));
179         B(3,4)=(R32X(k));
180         B(3,5)=(0);
181         B(3,6)=(0);
182         B(3,7)=(0);
183         B(3,8)=(0);
184         B(3,9)=(1);
185         B(4,1)=(0);
186         B(4,2)=(0);
187         B(4,3)=(-1);
188         B(4,4)=(0);
189         B(4,5)=(1);
190         B(4,6)=(0);
191         B(4,7)=(0);
192         B(4,8)=(0);
193         B(4,9)=(0);
194         B(5,1)=(0);
195         B(5,2)=(0);
196         B(5,3)=(0);
197         B(5,4)=(-1);
198         B(5,5)=(0);
199         B(5,6)=(1);
200         B(5,7)=(0);
201         B(5,8)=(0);
202         B(5,9)=(0);
203         B(6,1)=(0);
```

```
204       B(6,2)=(0);
205       B(6,3)=(-R23Y(k));
206       B(6,4)=(-R23X(k));
207       B(6,5)=(-R43Y(k));
208       B(6,6)=(R43X(k));
209       B(6,7)=(0);
210       B(6,8)=(0);
211       B(6,9)=(0);
212       B(7,1)=(0);
213       B(7,2)=(0);
214       B(7,3)=(0);
215       B(7,4)=(0);
216       B(7,5)=(-1);
217       B(7,6)=(0);
218       B(7,7)=(1);
219       B(7,8)=(0);
220       B(7,9)=(0);
221       B(8,1)=(0);
222       B(8,2)=(0);
223       B(8,3)=(0);
224       B(8,4)=(0);
225       B(8,5)=(0);
226       B(8,6)=(-1);
227       B(8,7)=(0);
228       B(8,8)=(1);
229       B(8,9)=(0);
230       B(9,1)=(0);
231       B(9,2)=(0);
232       B(9,3)=(0);
233       B(9,4)=(0);
234       B(9,5)=(R34Y(k));
235       B(9,6)=(-R34X(k));
236       B(9,7)=(-R14Y(k));
237       B(9,8)=(R14X(k));
238       B(9,9)=(0);
239
240       H(1,1)=(M2*AG2X(k));
241       H(1,2)=(M2*AG2Y(k));
242       H(1,3)=(IG2*AL2);
243       H(1,4)=(M3*AG4X(k)-FPX);
244       H(1,5)=(M3*AG4Y(k)-FPY);
245
246       H(1,6)=(IG3*AL3(k)-RPX(k)*FPY+RPY(k)*FPX);
247       H(1,7)=(M4*AG4X(k));
248       H(1,8)=(M4*AG4Y(k));
249       H(1,9)=(IG4*AL4(k)-T4);
250
251
252   end
253
254
255
256   %Plot(TH2,Vc,'-',TH2,Ac,'-',TH2,OM4,'-',TH2,AL4,'-');
257   %Plot(TH2,Vc);
258   %xlabel('TH 2');
259   %ylabel('Velocity');
260   %title('Velocity vs. TH 2');
261   %Plot(TH2,Ac);
262   %xlabel('TH 2');
263   %ylabel('Acceleration');
264   %title('Acceleration vs. TH 2');
265   %Plot(TH2,OM4);
266   %xlabel('TH 2');
267   %ylabel('OM 4');
268   %title('OM 4 vs. TH 2');
269
270   %Plot(TH2,AL4);
271   %xlabel('TH 2');
272   %ylabel('AL 4');
```

```
273   %title('AL 4 vs. TH 2');
```

```
format long e;
R1=2.22;
R2=1;
R3=2.06;
R4=2.33;
TH2=0:0.001:2*pi;
TH3=zeros(size(TH2));
TH4=zeros(size(TH2));
TH31=zeros(size(TH2));
TH41=zeros(size(TH2));
TH32=zeros(size(TH2));
TH42=zeros(size(TH2));
OM2=zeros(size(TH2));
OM3=zeros(size(TH2));
OM4=zeros(size(TH2));
AL3=zeros(size(TH2));
AL4=zeros(size(TH2));
A=zeros(2,2);
g=zeros(2,1);
q=zeros(2,1);
B=zeros(9,9);
H=zeros(9,1);
psi=(31-12.401)*(pi/180);
d=(1.6470);
R12X=zeros(size(TH2));
R12Y=zeros(size(TH2));
R32X=zeros(size(TH2));
R32Y=zeros(size(TH2));
R23X=zeros(size(TH2));
R23Y=zeros(size(TH2));
R43X=zeros(size(TH2));
R43Y=zeros(size(TH2));
R34X=zeros(size(TH2));
R34Y=zeros(size(TH2));
R14X=zeros(size(TH2));
R14Y=zeros(size(TH2));


n=max(size(TH2));
for k=1:n;
    theta2=TH2(k);
    K1=R1/R2;
    K2=R1/R4;
    K3=(R1^2+R2^2+R4^2-R3^2)/(2*R2*R4);
    K4=R1/R3;
    K5=(R4^2-R1^2-R2^2-R3^2)/(2*R2*R3);
    D=(1+K4)*cos(theta2)+K5-K1;
    F=(K4-1)*cos(theta2)+K5+K1;
    A=cos(TH2)-K1-K2*cos(TH2(k))+K3;
    B=-2*sin(theta2);
    C=K1-(K2+1)*cos(theta2)+K3;
    z1=(-B+sqrt(B^2-4*A*C))/(2*A);
    z2=(-B-sqrt(B^2-4*A*C))/(2*A);
    w1=(-B+sqrt(B^2-4*D*F))/(2*D);
    w2=(-B-sqrt(B^2-4*D*F))/(2*D);
    L1=2*z1/(1+z1^2);
    M1=(1-z1^2)/(1+z1^2);
    L2=2*z2/(1+z2^2);
    M2=(1-z2^2)/(1+z2^2);
    N1=2*w1/(1+w1^2);
    P1=(1-w1^2)/(1+w1^2);
    N2=2*w2/(1+w2^2);
    P2=(1-w2^2)/(1+w2^2);
    TH41(k)=atan2(L1,M1);
    TH42(k)=atan2(L2,M2);
    TH31(k)=atan2(N1,P1);
    TH32(k)=atan2(N2,P2);
end

```

```
OM2(1)=40;
AL2=-2;

for k=2:n;
    OM2(k)=sqrt(OM2(1)^2+2*AL2*TH2(k));
end

for k=1;n;
    TH3(k)=TH32(k);
    TH4(k)=TH42(k);
end
for k=1:n;
    R12X(k)=-R2*cos(TH2(k))/2;
    R12Y(k)=-R2*sin(TH2(k))/2;
    R32X(k)=-R12X(k);
    R32Y(k)=-R12Y(k);
    R23X(k)=-d*cos(TH3(k)-psi);
    R23Y(k)=-d*sin(TH3(k)-psi);
    R43X(k)=R3*cos(TH3(k)) + R23X(k);
    R43Y(k)=R3*sin(TH3(k)) + R23Y(k);
    R34X(k)=.5*R4*cos(TH4(k));
    R34Y(k)=.5*R4*sin(TH4(k));
    R14X(k)=-R34X(k);
    R14Y(k)=-R34Y(k);
    A(1,1)=R3*cos(TH3(k));
    A(1,2)=-R4*cos(TH4(k));
    A(2,1)=R3*sin(TH3(k));
    A(2,2)=-R4*sin(TH4(k));
    g(1)= -R2*OM2(k)*cos(TH2(k));
    g(2)= -R2*OM2(k)*sin(TH2(k));
    h=A\g;
    OM3(k)=h(1);
    OM4(k)=h(2);
    q(1)=-R2*AL2*cos(TH2(k))+R2*OM2(k)^2*sin(TH2(k))+R3*OM3(k)^2*sin(TH3(k)) - R4*OM4(k)^
    2*sin(TH4(k));
    q(2)=-R2*AL2*sin(TH2(k))-R2*OM2(k)^2*cos(TH2(k))+R3*OM3(k)^2*cos(TH3(k)) + R4*OM4(k)^
    2*cos(TH4(k));
    p=A\q;
    AL3(k)=p(1);
    AL4(k)=p(2);
    B(1,1)=(1);
    B(1,2)=(0);
    B(1,3)=(1);
    B(1,4)=(0);
    B(1,5)=(0);
    B(1,6)=(0);
    B(1,7)=(0);
    B(1,8)=(0);
    B(1,9)=(0);
    B(2,1)=(0);
    B(2,2)=(1);
    B(2,3)=(0);
    B(2,4)=(1);
    B(2,5)=(0);
    B(2,6)=(0);
    B(2,7)=(0);
    B(2,8)=(0);
    B(2,9)=(0);
    B(3,1)=(-R12Y(k));
    B(3,2)=(R12X(k));
    B(3,3)=(-R32Y(k));
    B(3,4)=(R32X(k));
    B(3,5)=(0);
    B(3,6)=(0);
    B(3,7)=(0);
    B(3,8)=(0);
    B(3,9)=(0);
    B(4,1)=(0);
    B(4,2)=(0);
```

```
137       B(4,3)=(-1);
138       B(4,4)=(0);
139       B(4,5)=(1);
140       B(4,6)=(0);
141       B(4,7)=(0);
142       B(4,8)=(0);
143       B(4,9)=(0);
144       B(5,1)=(0);
145       B(5,2)=(0);
146       B(5,3)=(0);
147       B(5,4)=(-1);
148       B(5,5)=(0);
149       B(5,6)=(1);
150       B(5,7)=(0);
151       B(5,8)=(0);
152       B(5,9)=(0);
153       B(6,1)=(0);
154       B(6,2)=(0);
155       B(6,3)=(-R23Y(k));
156       B(6,4)=(-R23X(k));
157       B(6,5)=(-R43Y(k));
158       B(6,6)=(R43X(k));
159       B(6,7)=(0);
160       B(6,8)=(0);
161       B(6,9)=(0);
162       B(7,1)=(0);
163       B(7,2)=(0);
164       B(7,3)=(0);
165       B(7,4)=(0);
166       B(7,5)=(-1);
167       B(7,6)=(0);
168       B(7,7)=(1);
169       B(7,8)=(0);
170       B(7,9)=(0);
171       B(8,1)=(0);
172       B(8,2)=(0);
173       B(8,3)=(0);
174       B(8,4)=(0);
175       B(8,5)=(0);
176       B(8,6)=(-1);
177       B(8,7)=(0);
178       B(8,8)=(1);
179       B(8,9)=(0);
180       B(9,1)=(0);
181       B(9,2)=(0);
182       B(9,3)=(0);
183       B(9,4)=(0);
184       B(9,5)=(R34Y(k));
185       B(9,6)=(-R34X(k));
186       B(9,7)=(-R14Y(k));
187       B(9,8)=(R14X(k));
188       B(9,9)=(0);
189
190   end
191
192
193
194
```

```
format short e;
J=zeros(2,2);

d=7.487;
a=9.174;
b=12.971;
c=9.573;
p=15;
MINVAL = -26;
MAXVAL = -20.55;
delta = 0.25;

Maxits=500;
Tol=1.0e-6;

X=[4;2];

for i=MINVAL:delta:MAXVAL;

    theta2=i*(pi/180);

for i=1:Maxits;
    theta3=X(1);
    theta4=X(2);

    F1=a*cos(theta2)+b*cos(theta3)-c*cos(theta4)-d;
    F2=a*sin(theta2)+b*sin(theta3)-c*sin(theta4);

    J(1,1)=-b*sin(theta3);
    J(1,2)=c*sin(theta4);
    J(2,1)=b*cos(theta3);
    J(2,2)=-c*cos(theta4);

    deltaX=inv(J)*[-F1;-F2];
    X=X+deltaX;

    theta3=X(1);
    theta4=X(2);

    F1check=abs(a*cos(theta2)+b*cos(theta3)-c*cos(theta4)-d);
    F2check=abs(a*sin(theta2)+b*sin(theta3)-c*sin(theta4));

    Fmax=max([F1check,F2check]);
    if Fmax<Tol
        break
    end
end

if i<Maxits
    fprintf('\n')
    fprintf('********** Newton Raphson Method **********\n\n');
    fprintf('Position Analysis:\n');
    fprintf('Inputs:\n');
    fprintf('a = %-2g mm  b = %-2g mm  c = %-2g mm  d = %-2g mm  theta2 = %-2.2f degrees'
    ,a,b,c,d,theta2*180/pi');
    fprintf('\nIterations=%-5g\n',i);
    fprintf('Outputs:\n');
    fprintf('theta3 = %-6.2f degrees',X(1)*180/pi);
    fprintf('  theta4 = %-6.2f degrees\n',X(2)*180/pi);
else
    fprintf('we did not converge!\n');
end

theta3=X(1);
theta4=X(2);
w2=2;

w3 = (a*sin(theta4 - theta2))/(b*sin(theta3-theta4))*w2;
w4 = (a*sin(theta2 - theta3))/(c*sin(theta4-theta3))*w2;
```

```
69
70  fprintf('\nVelocity Analysis:\n');
71  fprintf('Inputs:\n');
72  fprintf('w2 = %-2g rad/s\n',w2);
73  fprintf('Outputs:\n');
74  fprintf('w3 = %-6.2f rad/s',w3);
75  fprintf('  w4 = %-6.2f rad/s\n',w4);
76
77  A = c*sin(theta4);
78  B = b*sin(theta3);
79  C = a*(w2^2)*cos(theta2)+b*(w3^2)*cos(theta3)-c*(w4^2)*cos(theta4);
80  D = c*cos(theta4);
81  E = b*cos(theta3);
82  F = -a*(w2^2)*sin(theta2)-b*(w3^2)*sin(theta3)+c*(w4^2)*sin(theta4);
83
84  a3 = (C*D-A*F)/(A*E-B*D);
85  a4 = (C*E-B*F)/(A*E-B*D);
86
87  Vax = a*w2*-sin(theta2);
88  Vpax = p*w3*-sin(theta3);
89
90  Vay = a*w2*cos(theta2);
91  Vpay = p*w3*cos(theta3);
92
93  Vpx = Vax+Vpax;
94  Vpy = Vay+Vpay;
95
96  Vp = sqrt(Vpx^2+Vpy^2);
97
98  Aax = -a*w2^2*cos(theta2);
99  Apax = p*a3*-sin(theta3)-p*w3^2*cos(theta3);
100
101 Aay = -a*w2^2*sin(theta2);
102 Apay = p*a3*cos(theta3)-p*w3^2*sin(theta3);
103
104 Apx = Aax+Apax;
105 Apy = Aay+Apay;
106
107 Ap = sqrt(Apx^2+Apy^2);
108
109 fprintf('\nAcceleration Analysis:');
110 fprintf('\nOutputs:\n');
111 fprintf('a3 = %-6.2f rad/s^2',a3);
112 fprintf('  a4 = %-6.2f rad/s^2\n\n',a4);
113 fprintf('Vp = %-6.2f in/s\n',Vp);
114 fprintf('Ap = %-6.2f in/s\n',Ap);
115
116 end
117
```

```
format short e;
J=zeros(2,2);
R1=8;
R2=4;
R3=7;
R4=6;
TH2=[0:pi/12:pi/2];
TH3=zeros(size(TH2));
TH4=zeros(size(TH2));
TH31=zeros(size(TH2));
TH41=zeros(size(TH2));
TH32=zeros(size(TH2));
TH42=zeros(size(TH2));
n=max(size(TH2));
for k=1:n;
    theta2=TH2(k);
Maxits=500;
To1=1.0e-6;
X=[4;2];

for i=1:Maxits;
    theta3=X(1);
    theta4=X(2);
    F1=R2*cos(theta2)+R3*cos(theta3)-R4*cos(theta4)-R1;
    F2=R2*sin(theta2)+R3*sin(theta3)-R4*sin(theta4);
    J(1,1)=-R3*sin(theta3);
    J(1,2)=R4*sin(theta4);
    J(2,1)=R3*cos(theta3);
    J(2,2)=-R4*cos(theta4);
    deltaX=inv(J)*[-F1;-F2];
    X=X+deltaX;
    theta3=X(1);
    theta4=X(2);
    F1check=abs(R2*cos(theta2)+R3*cos(theta3)-R4*cos(theta4)-R1);
    F2check=abs(R2*sin(theta2)+R3*sin(theta3)-R4*sin(theta4));
    Fmax=max([F1check,F2check]);
    if Fmax<To1
        break
    end
end

N1=floor(X(1)/(2*pi));
N2=floor(X(2)/(2*pi));
J1=X(1)-(2*N1)*pi;
J2=X(2)-(2*N2)*pi;
if pi>J1
    X(1)=J1;
else
    X(1)=J1-2*pi;
end
if pi>J2
    X(2)=J2;
else
    X(2)=J2-2*pi;
end
if i<Maxits
    fprintf('theta2=%-6.2f degrees\n',TH2(k)*180/pi)
    fprintf('Iterations=%-5g\n\n',i);
    fprintf('theta3=%-6.2f degrees\n',X(1)*180/pi);
    fprintf('theta4=%-6.2f degrees\n',X(2)*180/pi);
else
    fprintf('theta2=%-6.2f degrees\n',TH2(k)*180/pi);
    fprintf('we did not converge!\n');
end

K1=R1/R2;
K2=R1/R4;
K3=(R1^2+R2^2+R4^2-R3^2)/(2*R2*R4);
K4=R1/R3;
```

```
K5=(R4^2-R1^2-R2^2-R3^2)/(2*R2*R3);
D=(1+K4)*cos(theta2)+K5-K1;
F=(K4-1)*cos(theta2)+K5+K1;
A=cos(theta2)-K1-K2*cos(theta2)+K3;
B=-2*sin(theta2);
C=K1-(K2+1)*cos(theta2)+K3;
z1=(-B+sqrt(B^2-4*A*C))/(2*A);
z2=(-B-sqrt(B^2-4*A*C))/(2*A);
w1=(-B+sqrt(B^2-4*D*F))/(2*D);
w2=(-B-sqrt(B^2-4*D*F))/(2*D);
L1=2*z1/(1+z1^2);
M1=(1-z1^2)/(1+z1^2);
L2=2*z2/(1+z2^2);
M2=(1-z2^2)/(1+z2^2);
N1=2*w1/(1+w1^2);
P1=(1-w1^2)/(1+w1^2);
N2=2*w2/(1+w2^2);
P2=(1-w2^2)/(1+w2^2);
TH41(k)=(180/pi)*atan2(L1,M1);
TH42(k)=(180/pi)*atan2(L2,M2);
TH31(k)=(180/pi)*atan2(N1,P1);
TH32(k)=(180/pi)*atan2(N2,P2);

fprintf('theta31=%-6.2f degrees\n',TH31(k));
    fprintf('theta32=%-6.2f degrees\n',TH32(k));
    fprintf('theta41=%-6.2f degrees\n',TH41(k));
    fprintf('theta42=%-6.2f degrees\n',TH42(k));
end
```

```
format short g; J=zeros(5,5);
R2= 28; R3=66; R5=33; R6=93.56; theta2=1.29; gamma=0.8594; theta6=0.17197;

Maxits=500;
Tol=1.0e-6;

X=[-.422; 68.2; .442; 60.2; -.432];

for i=1:Maxits;
    theta3=X(1); d1=X(2); theta5=X(3); d4=X(4); theta4=X(5);
    F1=R2*cos(theta2)+R3*cos(theta3)-d1;
    F2=R2*sin(theta2)+R3*sin(theta3);
    F3=R2*cos(theta2)+R5*cos(theta5)-d4*cos(theta4)-R6*cos(theta6);
    F4=R2*sin(theta2)+R5*sin(theta5)-d4*sin(theta4)-R6*sin(theta6);
    F5=theta5-theta3-gamma;

    J(1,1)=-R3*sin(theta3);
    J(1,2)=-1;
    J(2,1)=R3*cos(theta3);
    J(3,3)=-R5*sin(theta5);
    J(3,4)=-cos(theta4);
    J(3,5)=d4*sin(theta4);
    J(4,3)=R5*cos(theta5);
    J(4,4)=-sin(theta4);
    J(4,5)=-d4*cos(theta4);
    J(5,1)=-1;
    J(5,3)=1;

    deltaX=inv(J)*[-F1;-F2;-F3;-F4;-F5];
    X=X+deltaX;

    theta3=X(1); d1=X(2); theta5=X(3); d4=X(4); theta4=X(5);
    F1check=abs(+R2*cos(theta2)+R3*cos(theta3)-d1);
    F2check=abs(+R2*sin(theta2)+R3*sin(theta3));
    F3check=abs(+R2*cos(theta2)+R5*cos(theta5)-d4*cos(theta4)-R6*cos(theta6));
    F4check=abs(+R2*sin(theta2)+R5*sin(theta5)-d4*sin(theta4)-R6*sin(theta6));
    F5check=abs(+theta5-theta3-gamma);

    Fmax=max([F1check,F2check,F2check,F3check,F4check,F5check]);
    if Fmax<Tol
        break
    end
end

if i<Maxits fprintf('\n')
    fprintf('Iterations = %-5g\n\n',i)
    fprintf('theta3 = %-6.2f degrees\n',X(1)*180/pi);
    fprintf('d1 = %-6.2f \n',X(2));
    fprintf('theta5 = %-6.2f degrees\n',X(3)*180/pi);
    fprintf('d4 = %-6.2f \n',X(4));
    fprintf('theta4 = %-6.2f degrees\n',X(5)*180/pi);
else
    fprintf('We did not converge!!!!!\n')
end

omega2=-2;

z=[omega3; dotd1; dotd4; omega4];
A=zeros(4,4);

G1=-R2*sin(theta2)*omega2-R3*sin(theta3)*omega3-dotd1;
G2=R2*cos(theta2)*omega2+R3*cos(theta3)*omega3;
G3=-R2*sin(theta2)*omega2-+d4*sin(theta4)*omega4-cos(theta4)*dotd4-R5sin(theta5)*omega3;
G4=R2*cos(theta2)*omega2-d4*cos(theta4)*omega4-sin(theta4)*dotd4+R5*cos(theta5)*omega3;

A(1,1)=-R3*sin(theta3);
A(1,2)=-1;
A(2,1)=R3*cos(theta3);
A(3,1)=-R5*sin(theta5);
```

```
A(3,3)=-cos(theta4);
A(3,4)=d4*sin(theta4);
A(4,1)=R5*cos(theta5);
A(4,3)=-sin(theta4);
A(4,4)=-d4*cos(theta4);

g1=R2*sin(theta2)*omega2;
g2=-R2*cos(theta2)*omega2;
G=[g1;g2;g1;g2];

z=inv(A)*G;


    fprintf('theta3 = %-6.2f degrees\n',X(1)*180/pi);
    fprintf('d1 = %-6.2f \n',X(2));
    fprintf('theta5 = %-6.2f degrees\n',X(3)*180/pi);
    fprintf('d4 = %-6.2f \n',X(4));
    fprintf('theta4 = %-6.2f degrees\n',X(5)*180/pi);

```