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MAE 150 HW 3 Problem 2

```
clear
close all

% 5th Degree Polynomial Fit
y = [0 0.1 0.3 0.7 1.2 1.8 2.5 3.3 4.1 5 5.9 6.7 7.5 8.2 8.8 9.3 9.7 9.9 10]';
theta = (0:5:90)';

M = length(y);
x = theta;
A = [        M    sum(x) sum(x.^2) sum(x.^3) sum(x.^4) sum(x.^5);
        sum(x) sum(x.^2) sum(x.^3) sum(x.^4) sum(x.^5) sum(x.^6);
     sum(x.^2) sum(x.^3) sum(x.^4) sum(x.^5) sum(x.^6) sum(x.^7);
     sum(x.^3) sum(x.^4) sum(x.^5) sum(x.^6) sum(x.^7) sum(x.^8);
     sum(x.^4) sum(x.^5) sum(x.^6) sum(x.^7) sum(x.^8) sum(x.^9);
     sum(x.^5) sum(x.^6) sum(x.^7) sum(x.^8) sum(x.^9) sum(x.^10)];
b = [      sum(y);
        sum(y.*x);
     sum(y.*x.^2);
     sum(y.*x.^3);
     sum(y.*x.^4);
     sum(y.*x.^5)];

a = A\b;
```

Define functions

```
dtheta = 1;
omega = 250*360/60;

% 5th Degree Polynomial Rise
beta = 90;
theta = (0:dtheta:beta)';
y_1 = (a(1) + a(2)*theta + a(3)*theta.^2 + a(4)*theta.^3 + a(5)*theta.^4 +
 a(6)*theta.^5)/10^3;
v_1 = (a(2)*omega + 2*a(3)*omega*theta + 3*a(4)*omega*theta.^2 +
 4*a(5)*omega*theta.^3 + 5*a(6)*omega*theta.^4)/10^3;
a_1 = (2*a(3)*omega^2 + 6*a(4)*omega^2*theta + 12*a(5)*omega^2*theta.^2 +
 20*a(6)*omega^2*theta.^3)/10^3;
j_1 = (6*a(4)*omega^3 + 24*a(5)*omega^3*theta +
 60*a(6)*omega^3*theta.^2)/10^3;
```

```
% Dwell
beta = 120 - 90;
theta = (0:dtheta:beta)';
L = 10/10^3;
y_2 = L*ones(length(theta),1);
v_2 = zeros(length(theta),1);
a_2 = zeros(length(theta),1);
j_2 = zeros(length(theta),1);

% Harmonic Rise
beta = 180 - 120;
theta = (0:dtheta:beta)';
L = (20 - 10)/10^3;
y_3 = L/2*(1-cos(pi*theta/beta));
v_3 = L/2*pi*omega/beta*sin(pi*theta/beta);
a_3 = L/2*(pi*omega/beta)^2*cos(pi*theta/beta);
j_3 = -L/2*(pi*omega/beta)^3*sin(pi*theta/beta);

% Dwell
beta = 210 - 180;
theta = (0:dtheta:beta)';
L = 20/10^3;
y_4 = L*ones(length(theta),1);
v_4 = zeros(length(theta),1);
a_4 = zeros(length(theta),1);
j_4 = zeros(length(theta),1);

% Cycloidal Rise
beta = 280 - 210;
theta = (0:dtheta:beta)';
L = (32 - 20)/10^3;
y_5 = L*(theta/beta - 1/(2*pi)*sin(2*pi*theta/beta));
v_5 = L*omega/beta*(1 - cos(2*pi*theta/beta));
a_5 = 2*L*pi*(omega/beta)^2*sin(2*pi*theta/beta);
j_5 = 4*L*pi^2*(omega/beta)^3*cos(2*pi*theta/beta);

% Dwell
beta = 300 - 280;
theta = (0:dtheta:beta)';
L = 32/10^3;
y_6 = L*ones(length(theta),1);
v_6 = zeros(length(theta),1);
a_6 = zeros(length(theta),1);
j_6 = zeros(length(theta),1);

% 3-4-5 Polynomial Fall
beta = 360 - 300;
theta = (0:dtheta:beta)';
L = 32/10^3;
y_7 = L - L*(10*theta.^3/beta^3 - 15*theta.^4/beta^4 + 6*theta.^5/beta^5);
v_7 = -L*(30*omega*theta.^2/beta^3 - 60*omega*theta.^3/beta^4 +
 30*omega*theta.^4/beta^5);
a_7 = -L*(60*omega^2*theta/beta^3 - 180*omega^2*theta.^2/beta^4 +
 120*omega^2*theta.^3/beta^5);
```

```
j_7 = -L*(60*omega^3/beta^3 - 360*omega^3*theta/beta^4 + 360*omega^3*theta.^2/
beta^5);
```

(a) Plotting

```
theta = (0:dtheta:360)';

color = ('rygcbmk');
linewidth = 3;
fontsize = 14;

fprintf('Part (a)\n')
figure

subplot(2,2,1)
plot(theta(1:91),y_1,color(1))
hold on
plot(theta(91:121),y_2,color(2))
plot(theta(121:181),y_3+10/10^3,color(3))
plot(theta(181:211),y_4,color(4))
plot(theta(211:281),y_5+20/10^3,color(5))
plot(theta(281:301),y_6,color(6))
plot(theta(301:361),y_7,color(7))
hold off
title('Displacement Profile')
xlabel('\theta (\circ)')
ylabel('Displacement (m)')
xticks(0:90:360)
h = gca;
h.XAxis.MinorTick = 'on';
h.XAxis.MinorTickValues = 0:30:360;
grid on
grid minor
set(h,'DefaultLineLineWidth',linewidth,'FontSize',fontsize)

subplot(2,2,2)
plot(theta(1:91),v_1,color(1))
hold on
plot(theta(91:121),v_2,color(2))
plot(theta(121:181),v_3,color(3))
plot(theta(181:211),v_4,color(4))
plot(theta(211:281),v_5,color(5))
plot(theta(281:301),v_6,color(6))
plot(theta(301:361),v_7,color(7))
hold off
title('Velocity Profile')
xlabel('\theta (\circ)')
ylabel('Velocity (m/s)')
xticks(0:90:360)
h = gca;
h.XAxis.MinorTick = 'on';
h.XAxis.MinorTickValues = 0:30:360;
grid on
```

```
grid minor
set(h,'DefaultLineLineWidth',linewidth,'FontSize',fontsize)

subplot(2,2,3)
plot(theta(1:91),a_1,color(1))
hold on
plot(theta(91:121),a_2,color(2))
plot(theta(121:181),a_3,color(3))
plot(theta(181:211),a_4,color(4))
plot(theta(211:281),a_5,color(5))
plot(theta(281:301),a_6,color(6))
plot(theta(301:361),a_7,color(7))
hold off
title('Acceleration Profile')
xlabel('\theta (\circ)')
ylabel('Acceleration (m/s^2)')
xticks(0:90:360)
h = gca;
h.XAxis.MinorTick = 'on';
h.XAxis.MinorTickValues = 0:30:360;
grid on
grid minor
set(h,'DefaultLineLineWidth',linewidth,'FontSize',fontsize)

subplot(2,2,4)
plot(theta(1:91),j_1,color(1))
hold on
plot(theta(91:121),j_2,color(2))
plot(theta(121:181),j_3,color(3))
plot(theta(181:211),j_4,color(4))
plot(theta(211:281),j_5,color(5))
plot(theta(281:301),j_6,color(6))
plot(theta(301:361),j_7,color(7))
stem(0,10^4,color(1),'marker','^','ShowBaseLine','off')
stem(90,10^4,color(1),'marker','^','ShowBaseLine','off')
stem(120,10^4,color(3),'marker','^','ShowBaseLine','off')
stem(180,10^4,color(3),'marker','^','ShowBaseLine','off')
hold off
title('Jerk Profile')
xlabel('\theta (\circ)')
ylabel('Jerk (m/s^3)')
xticks(0:90:360)
h = gca;
h.XAxis.MinorTick = 'on';
h.XAxis.MinorTickValues = 0:30:360;
grid on
grid minor
set(h,'DefaultLineLineWidth',linewidth,'FontSize',fontsize)

legend('5th Deg Polynomial Rise','Dwell','Harmonic Rise','Dwell','Cycloidal
 Rise','Dwell','3-4-5 Polynomial Fall')
legend("Position", [0.36,0.7,0.32,0.28])
```

```
sgtitle(sprintf('(a) Cam Profiles\n\n\n\n\n
\n'),'fontsize',1.25*fontsize,'fontweight','bold')
```

(b) Pressure Angle

```
R_0 = (45 + 6)/10^3;

dy1dth = v_1/omega*180/pi;
dy2dth = v_2/omega*180/pi;
dy3dth = v_3/omega*180/pi;
dy4dth = v_4/omega*180/pi;
dy5dth = v_5/omega*180/pi;
dy6dth = v_6/omega*180/pi;
dy7dth = v_7/omega*180/pi;

phi_1 = atand(dy1dth./(R_0 + y_1));
phi_2 = atand(dy2dth./(R_0 + y_2));
phi_3 = atand(dy3dth./(R_0 + y_3 + 10/10^3));
phi_4 = atand(dy4dth./(R_0 + y_4));
phi_5 = atand(dy5dth./(R_0 + y_5 + 20/10^3));
phi_6 = atand(dy6dth./(R_0 + y_6));
phi_7 = atand(dy7dth./(R_0 + y_7));

fprintf('Part (b)\n')
figure
plot(theta(1:91),phi_1,color(1))
hold on
plot(theta(91:121),phi_2,color(2))
plot(theta(121:181),phi_3,color(3))
plot(theta(181:211),phi_4,color(4))
plot(theta(211:281),phi_5,color(5))
plot(theta(281:301),phi_6,color(6))
plot(theta(301:361),phi_7,color(7))
hold off
title('Pressure Angle vs. \theta')
xlabel('\theta (\circ)')
ylabel('Pressure Angle (\circ)')
xticks(0:90:360)
h = gca;
h.XAxis.MinorTick = 'on';
h.XAxis.MinorTickValues = 0:30:360;
grid on
grid minor
set(h,'DefaultLineLineWidth',linewidth,'FontSize',fontsize)
legend('5th Deg Polynomial Rise','Dwell','Harmonic Rise','Dwell','Cycloidal
 Rise','Dwell','3-4-5 Polynomial Fall','Location','best')

phi = [phi_1; phi_2(2:end); phi_3(2:end); phi_4(2:end); + phi_5(2:end);
 phi_6(2:end); phi_7(2:end)];
idx = ismember(theta,30:30:360);
table((0:30:360)',[0; round(phi(idx),4)],'VariableNames',{'theta (deg)','phi
 (deg)'})
```

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