The equation for the contribution of pitch due to the wing is:

$$C_{m_w} = C_{m_{0_w}} + C_{m_{\alpha_w}}$$

Where $C_{m_{0_w}} = C_{m_{ac_w}} + C_{L_{0_w}} \left(\frac{x_{cg}}{\bar{c}} - \frac{x_{ac}}{\bar{c}})\right)$ and $C_{m_{\alpha_w}} = C_{L_{\alpha_w}} \left(\frac{x_{cg}}{\bar{c}} - \frac{x_{ac}}{\bar{c}})\right)$

The wing contribution to the pitching moment is:

$\boxed{C_{m_{\alpha_w}} = 0.002915 \text{ (1/deg)}}$ and $\boxed{C_{m_{0_w}} = \boxed{\text{-0.0997}}}$ a □

The equation for the contribution of pitch due to the tail is:

$$C_{m_t} = C_{m_{0_t}} + C_{m_{\alpha_t}}$$

Where $C_{m_{0_t}} = \eta V_H C_{L_{\alpha_t}} (\varepsilon + i_w - i_t)$ and $C_{m_{\alpha_t}} = -\eta V_H C_{L_{\alpha_t}} \left(1 - \frac{d\varepsilon}{d\alpha}\right)$

The tail contribution to the pitching moment is:

$\boxed{C_{m_{\alpha_t}} = -0.02008 \text{ (1/deg)}}$ and $\boxed{C_{m_{0_t}} = 0.1685}$ b □

The equation for the contribution of pitch due to the fuselage is:

$$C_{m_f} = C_{m_{0_f}} + C_{m_{\alpha_f}}$$

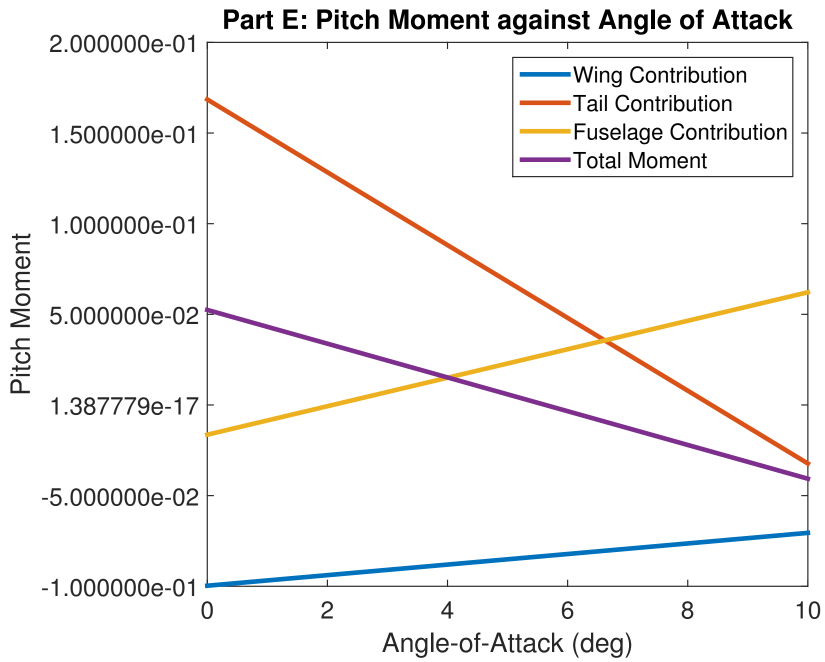
Where $C_{m_{0_f}} = \frac{k_2 - k_1}{36.5 S\bar{c}} * \sum_{x=0}^{x=l_f} w_f^2 (\alpha_{0_w} + i_f) \Delta x$ and $C_{m_{\alpha_t}} = \frac{1}{36.5 S\bar{c}} * \sum_{x=0}^{x=l_f} w_f^2 \frac{\partial \varepsilon}{\partial \alpha} \Delta x$

The fuselage contribution to the pitching moment is:

$\boxed{C_{m_{\alpha_f}} = 0.007855 \text{ (1/deg)}}$ and $\boxed{C_{m_{0_f}} = -0.0164}$ c □

The total contribution to the pitching moment is (due to roundoff error):

$\boxed{C_{m_{\alpha_{total}}} = -0.009311 \text{ (1/deg)}}$ and $\boxed{C_{m_{0_{total}}} = 0.05243}$ d □



e□

The stick fixed neutral point is (due to roundoff): 0.4097 f□

```
clear all; close all; clc
%Project 1
%Problem 1
fid = fopen('Project_2.txt','w+');

%Business Jet Aircraft Data
station = [1 2 3 4 5 6 7 8 9 10 11 12 13];
dx = [2.6 2.6 2.2 2.2 3.4 3.4 3.4 3.4 14.6 5.2 5.2
    5.2 5.2];
wf = [2.5 4.2 5.5 6.3 6.6 7.2 7.2 7.2 7.2 6.6 5.4
    3.8 2.1];
i_f = [-3 -3 -10 -10 0 0 0 0 0 0 0 0 -4];
%

% Wing Characteristics
S = 542.5; % ft^2
b = 53.75; % ft
cbar = 10.93; % ft
c_m_ac_w = -0.1;
c_l_alpha_w = 0.0583; % 1/deg
c_l_0_w = 0.006; % ---
i_w = 0; % deg
alpha_0_w = -1; % deg

% Tail Characteristics
S_t = 149; % ft^2
b_t = 24.75; % ft
cbar_t = 6.5; % ft
c_l_alpha_t = 0.05934; % 1/deg
i_t = -5; % deg
eta = 0.95;
l_t = 23.6; % ft

% Fuselage Characteristics
l_f = 58.6; % ft
d_max = 7.2; % ft
l_h = 14.2; % ft

```

```matlab
% Aircraft Characteristics
xcg = 0.25*cbar; % ft
xac = 0.2*cbar; % ft

%Part a; Wing Contribution to the Pitching Moment
Cm_alpha_w = c_l_alpha_w*(xcg/cbar-xac/cbar); % 1/deg (given answer 0.167 (1/rad) = 0. (1/deg))
a_Cm_alpha_w = 0.167*(pi/180);; % 1/deg
Cm_0_w = c_m_ac_w+c_l_0_w*(xcg/cbar-xac/cbar); % given answer -0.0997
a_Cm_0_w = -0.0997;
fprintf(fid,'\\noindent The equation for the contribution of pitch due to the wing is: \\\\n');
fprintf(fid,'\n $C_{m_{w}} = C_{m_{0_w}} + C_{m_{\\alpha_w}}$\\\\n');
fprintf(fid,'\\\\n Where $C_{m_{0_w}} = C_{m_{ac_w}}+C_{L_{0_w}}\\left(\\dfrac{x_{cg}}{\\bar{c}}-\\dfrac{x_{ac}}{\\bar{c}})\\right)$ and $C_{m_{\\alpha_w}} = C_{L_{\\alpha_w}}\\left(\\dfrac{x_{cg}}{\\bar{c}}-\\dfrac{x_{ac}}{\\bar{c}})\\right)$\\\\n');
fprintf(fid,'\\\\ The wing contribution to the pitching moment is:\\\\n \n $\\fbox{$C_{m_{\\alpha_w}} = %.4g$ (1/deg)}$ and $\\fbox{$C_{m_{0_w}} = \\fbox{%.4g}$}\\hspace*{\\fill} \\circled{a} \\square$\\\\n',Cm_alpha_w,Cm_0_w);
% if Cm_alpha_w == a_Cm_alpha_w
%       fprintf(fid,'\\\\ The $C_{m_{\\alpha_w}}$ contributions matches the answer given.\\\\n');
%       else
%       fprintf(fid,'\\\\ The $C_{m_{\\alpha_w}}$ calculated is %.4g and the answer is %.4g\\\\n',Cm_alpha_w,a_Cm_alpha_w);
% end
% if Cm_0_w == a_Cm_0_w
%       fprintf(fid,'\\\\ The $C_{m_{0_w}}$ contributions matches the answer given.\\\\n');
```

```
%        else
%        fprintf(fid,'The $C_{m_{0_w}}$ calculated is %.4g and the answer is %.4g\\\\n',Cm_0_w,a_Cm_0_w);
% end

% Part b; Tail contribution to the pitching moment
AR_w = b^2/S;
de_over_dalpha = (2*c_l_alpha_w)/(pi*AR_w)*(180/pi);
VH = (S_t/S)*(l_t/cbar);
Cm_alpha_t = -eta*VH*c_l_alpha_t*(1-de_over_dalpha); % 1/deg (given answer -1.1506 (1/rad))
a_Cm_alpha_t = -1.1506*(pi/180); % 1/deg;
eps0 = (2*c_l_0_w)/(pi*AR_w)*(180/pi); % deg
Cm_0_t = eta*VH*c_l_alpha_t*(eps0+i_w-i_t);
a_Cm_0_t = 0.1685;
fprintf(fid,'\\\\\nThe equation for the contribution of pitch due to the tail is: \\\\\n');
fprintf(fid,'\n $C_{m_{t}} = C_{m_{0_t}} + C_{m_{\\alpha_t}}$\\\\\n');
fprintf(fid,'\\\\\n Where $C_{m_{0_t}} = \\eta V_HC_{L_{\\alpha_t}}\\left(\\varepsilon+i_w-i_t\\right)$ and $C_{m_{\\alpha_t}} = -\\eta V_HC_{L_{\\alpha_t}}\\left(1-\\dfrac{d\\varepsilon}{d\\alpha}\\right)$\\\\\n');
fprintf(fid,'The tail contribution to the pitching moment is:\\\\\n \n $\\fbox{$C_{m_{\\alpha_t}} = %.4g$ (1/deg)}$ and $\\fbox{$C_{m_{0_t}} = %.4g$}\\hspace*{\\fill} \\circled{b} \\square$\\\\\n',Cm_alpha_t,Cm_0_t);
% if Cm_alpha_t == a_Cm_alpha_t
%        fprintf(fid,'\\\\The $C_{m_{\\alpha_t}}$ contributions matches the answer given.\\\\\n');
%        else
%        fprintf(fid,'\\\\The $C_{m_{\\alpha_t}}$ calculated is %.4g and the answer is %.4g\\\\n',Cm_alpha_t,a_Cm_alpha_t);
% end
```

```
% if Cm_0_t == a_Cm_0_t
%       fprintf(fid,'The $C_{m_{0_t}}$ contributions matches the answer given.\\\\n');
%       else
%       fprintf(fid,'The $C_{m_{0_t}}$ calculated is %.4g and the answer is %.4g\\\\n',Cm_0_t, a_Cm_0_t);
% end

%Part c; Fuselage contribution to the pitching moment
sum_cm_alpha_f = 0;
for i=10:length(station)
        if i == 10
        deu(i-9) = (dx(i)/2)/l_h*(1-de_over_dalpha);
        else
        deu(i-9) = (dx(i)/2+sum(dx(10:i)))/l_h*(1-de_over_dalpha);
    end
end
%deu_over_dalpha = [1.1 1.125 1.150 1.175 1.20 1.40 1.45 3.40 0];
deu_over_dalpha = [1.115 1.125 1.15 1.2 1.25 1.35 1.55 3.2 0];
deu_over_dalpha = cat(2,deu_over_dalpha,deu);
for i=1:length(station)
        sum_cm_alpha_f = sum_cm_alpha_f + wf(i)^2*deu_over_dalpha(i)*dx(i);
end
Cm_alpha_f = (1/(36.5*S*cbar))*sum_cm_alpha_f;
a_Cm_alpha_f = 0.0076; % 1/deg

dk2k1 = 0.9; %approximately
sum_cm_0_f = 0;
for i=1:length(station)
%       if i == 9
%               sum_cm_0_f = sum_cm_0_f + 0;
%       else
```

```
                    sum_cm_0_f = sum_cm_0_f + wf(i)^2*(alpha_0_w+i_f(i))*dx(i);
%        end
end
Cm_0_f = ((dk2k1)/(36.5*S*cbar))*sum_cm_0_f;
a_Cm_0_f = -0.0164;

fprintf(fid,'\\\\nThe equation for the contribution of pitch due to the fuselage is: \\\\n');
fprintf(fid,'\n $C_{m_{f}} = C_{m_{0_f}} + C_{m_{\\alpha_f}}$\\\\n');
fprintf(fid,'\\\\n Where $C_{m_{0_f}} = \\dfrac{k_2-k_1}{36.5S\\bar{c}}*\\sum_{x=0}^{x=l_f} w^2_f(\\alpha_{0_w} + i_f)\\Delta x$ and $C_{m_{\\alpha_t}} = \\dfrac{1}{36.5S\\bar{c}}*\\sum_{x=0}^{x=l_f} w^2_f \\dfrac{\\partial \\varepsilon}{\\partial \\alpha}\\Delta x$\\\\n');
fprintf(fid,'\\\\nThe fuselage contribution to the pitching moment is:\\\\n \n $\\fbox{$C_{m_{\\alpha_f}} = %.4g$ (1/deg)}$ and $\\fbox{$C_{m_{0_f}} = %.4g$}\\hspace*{\\fill} \\circled{c} \\square$\\\\n',Cm_alpha_f,Cm_0_f);
% if Cm_alpha_f == a_Cm_alpha_f
%       fprintf(fid,'\\\\The $C_{m_{\\alpha_f}}$ contributions matches the answer given.\\\\n');
%       else
%       fprintf(fid,'\\\\The $C_{m_{\\alpha_f}}$ calculated is %.4g and the answer is %.4g\\\\n',Cm_alpha_f,a_Cm_alpha_f);
% end
% if Cm_0_f == a_Cm_0_f
%       fprintf(fid,'The $C_{m_{0_f}}$ contributions matches the answer given.\\\\n');
%       else
%       fprintf(fid,'The $C_{m_{0_f}}$ calculated is %.4g and the answer is %.4g\\\\n',Cm_0_f,a_Cm_0_f);
% end
```

```
% Part d; Total pitching moment
total_Cm_alpha = (Cm_alpha_w*(180/pi)+Cm_alpha_t*(180/pi)+Cm_alpha_f*(180/pi))*(pi/180);
a_total_Cm_alpha = -0.548*(pi/180); % 1/deg
total_Cm_0 = Cm_0_w+Cm_0_t+Cm_0_f;
a_total_Cm_0 = 0.05243;
fprintf(fid,'\\\\\nThe total contribution to the pitching moment is (due to roundoff error):\\\\\n \n $\\fbox{$C_{m_{\\alpha_{total}}} = %.4g$ (1/deg)}$ and $\\fbox{$C_{m_{0_{total}}} = %.4g$}\\hspace*{\\fill} \\circled{d} \\square$\\\\\n',total_Cm_alpha,total_Cm_0);
% if total_Cm_alpha == a_total_Cm_alpha
%       fprintf(fid,'\\\\The $C_{m_{\\alpha_w}}$ contributions matches the answer given.\\\\\n');
%       else
%       fprintf(fid,'\\\\The $C_{m_{\\alpha_w}}$ calculated is %.4g and the answer is %.4g\\\\\n',total_Cm_alpha,a_total_Cm_alpha);
% end
% if total_Cm_0 == a_total_Cm_0
%       fprintf(fid,'The $C_{m_{0_}}$ contributions matches the answer given.\\\\\n');
%       else
%       fprintf(fid,' $C_{m_{0_w}}$ calculated is %.4g and the answer is %.4g\\\\\n',total_Cm_0,a_total_Cm_0);
% end
%Part e; plot various contributions and total pitch moment versus alpha
alpha = [0:1:10];
for i=1:11
    cm_w(i) = Cm_0_w + Cm_alpha_w*alpha(i);
    cm_t(i) = Cm_0_t + Cm_alpha_t*alpha(i);
    cm_f(i) = Cm_0_f + Cm_alpha_f*alpha(i);
    cm(i) = total_Cm_0 + total_Cm_alpha*alpha(i);
end
```

```

figure(1)
plot(alpha,cm_w,alpha,cm_t,alpha,cm_f,alpha,cm,'
    LineWidth',3.0)
title('Part E: Pitch Moment against Angle of Attack'
    );
ylabel('Pitch Moment');
xlabel('Angle-of-Attack (deg)');
legend('Wing Contribution','Tail Contribution', '
    Fuselage Contribution', 'Total Moment');
ax = gca;
ax.FontSize = 16;

name = 'Figure_1';
print(figure(1),'-depsc',name);
fprintf(fid,'\\begin{figure}[H]\\centering\\
    includegraphics[keepaspectratio=true,height=.45\\
    textheight,width=1\\textwidth]{%s.eps} $\\hspace
    *{\\fill} \\circled{e} \\square$\\end{figure}\n',
    name);

% Part f
xnp = xac/cbar - Cm_alpha_f/c_l_alpha_w + eta*VH*(
    c_l_alpha_t)/(c_l_alpha_w)*(1-de_over_dalpha);
fprintf(fid,'The stick fixed neutral point is (due
    to roundoff): %.4g $\\hspace*{\\fill} \\circled{f
    } \\square$',xnp);
fclose(fid);
```