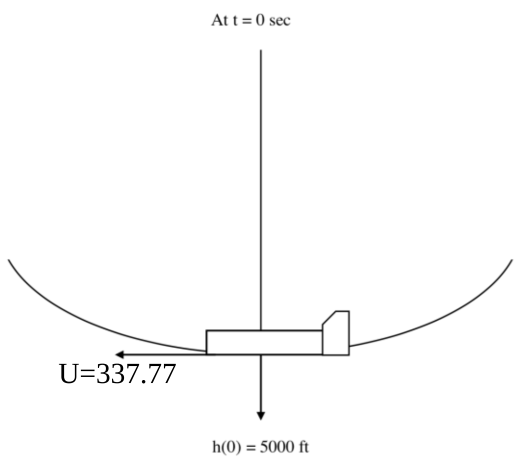
Homework 2 AAE 421 Due 09/29 5:00 pm **Name___________________**

Problem 1. (15pts)

An aircraft is flying straight and level at a constant velocity of 337. 77 ft/sec, and then performs a symmetric pull up such that $\dot{\Theta} = 0.05$ rad/s=constant. Assume the aircraft's x-axis is aligned with the flight path throughout the motion and that at $t = 0$, the aircraft's location in North-East-Altitude coordinate is $p_N = 0$, $p_E = 0$, and $h = 5000$ ft. Find the position coordinates (p_N, p_E, h) at $t = 5$ sec. Assume $\Psi = 0$.



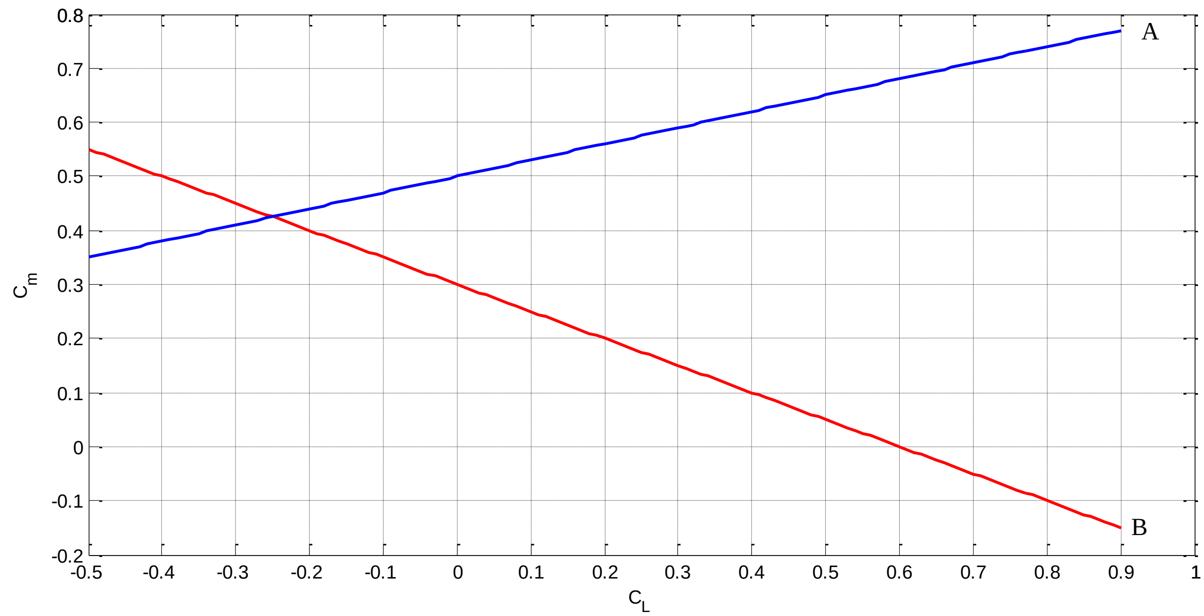
Problem 2. (10pts)

The aircraft velocity vector expressed in the Earth-fixed reference frame is
$\bar{V}_I = U\boldsymbol{I} + V\boldsymbol{J} + W\boldsymbol{K} = 6.6637\boldsymbol{I} + 289.1164\boldsymbol{J} - 407.8815\boldsymbol{K}$ (ft/sec)
and in the aircraft fixed body reference frame it is given by
$\bar{V}_b = u\boldsymbol{i} + v\boldsymbol{j} + w\boldsymbol{k} = 497.7939\boldsymbol{i} + 17.4497\boldsymbol{j} + 43.5513\boldsymbol{k}$ (ft/sec)
Find the attitude of the aircraft in terms of its Euler angles (Ψ, Θ, Φ). Is your answer unique?

Problem 3 (10pts)

For the C_L and C_m relationship shown in the following plots

(1) Find the linear expressions of C_m in term of C_L for line A and B, respectively.
(2) To obtain a trim condition, which line should be selected?
(3) Assuming $\frac{x_{cg}}{\bar{c}}$=0.6, how to relocate the a.c center ($\frac{x_{ac}}{\bar{c}}$) to obtain a new $C_{L,trim}$=0.8?



Problem 4. (15pts)

Wind tunnel test on a full-scale flying wing yielded the following database

Angle of Attack, deg	C_L	$C_{m_{cg}}$
8.0	0.64	-0.014
5.0	0.40	0.010
2.0	0.16	0.034
-3.0	-0.24	0.074

The configuration c.g is located 0.58 ft from the leading edge of the chord and the chord length is 2.6 ft.

(a) Estimate the configuration lift curve slope
(b) Is the configuration, as tested, statically stable? Explain your answer.
(c) Estimate values for C_m at the aerodynamic center and aerodynamic center location.
(d) Can this configuration, as tested, be trimmed in a steady glide condition? Explain your answer.
(e) If the answer to part (d) is yes, then estimate values for trim angle of attack and trim lift coefficient

Problem 5. (10pts)

Consider the following nonlinear 2nd-order system

$$\ddot{y} + a_1\dot{y}^2 + \frac{a_0}{y^2} = f$$

where a_0 and a_1 are constant, and $a_0 > 0$

(1) For a constant input $f = f_0 > 0$, determine the equilibrium points of the system
(2) Obtain the linearized equations of the system at the equilibrium points
(3) Express the linearized model in state equations, choosing $x_1 = \Delta y, x_2 = \Delta\dot{y}, u = \Delta f$

Problem 6. (10pts)

Consider an airplane in constant-altitude, straight-line flight. The velocity equation is

$$\dot{V} = T - \frac{1}{2}kV^2$$

where the second term represents aerodynamic drag, and assume k = constant, and T is the engine thrust acceleration. Treat T as the control (input). Let V^* be a given constant cruise speed. Obtain the linearized differential equation for the velocity around V^*.

Problem 7. (15pts)

From the nonlinear flight dynamics model, derive the following linear perturbation equations for Y force

$$m(\dot{v} + u_0 r) = \Delta Y + mgcos(\theta_0)\phi$$

and moments:

$$\Delta L = I_{xx}\dot{p} - I_{xz}\dot{r}$$
$$\Delta M = I_{yy}\dot{q}$$
$$\Delta N = -I_{xz}\dot{p} + I_{zz}\dot{r}$$

Show all the steps!

Problem 8. (15pts)

Consider the 2-degree-of-freedom spring mass pendulum shown below (All motion is in the plane of the picture shown). The nonlinear equations of motion are given by

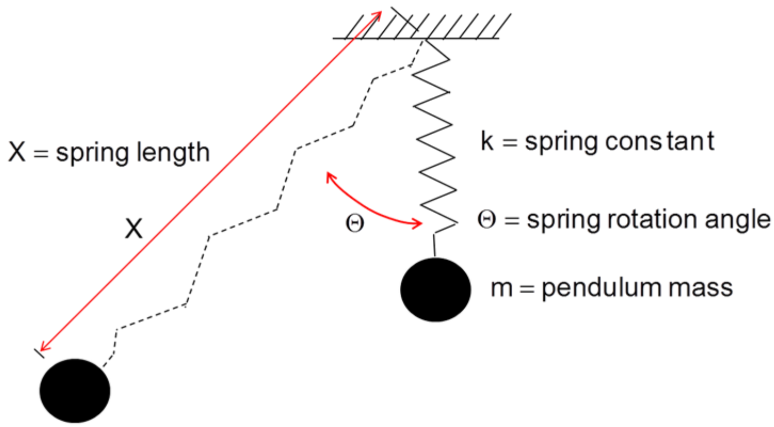
(1) $\ddot{X} + \frac{k}{m}(X - L) - gcos\Theta - X\dot{\Theta}^2 = 0$

(2) $X^2\ddot{\Theta} + gXsin\Theta + 2\dot{\Theta}X\dot{X} = 0$

where L is the original spring length.

Linearize the equations of motion for this system. Let the reference condition be the equilibrium (no motion) state for the pendulum mass. In particular

(a) Define a set of perturbation variables
(b) Substitute the results of Part (a) into the equations of motion
(c) Expand the equations and discard appropriate terms (show the terms that are to be discarded)


X = spring length
X
k = spring constant
Θ
Θ = spring rotation angle
m = pendulum mass