UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION, DECEMBER 2001
Fourth Year – Program 5a

AER 402F – Atmospheric Flight

Examiner – Professor L.D. Reid

Candidates may use any aids required. Candidates must answer all questions. You may freely use equations from notes or other aids *without derivation*, but you should indicate the source and discuss the limitations in your application. When expedient make use of reasonable simplifying assumptions.

All 3 questions are of equal value.

1. (a) What are trim tabs and how are they employed by the pilot?

   (b) What conditions hold when δ_e is equal to (i) $\delta_{e_{free}}$ and (ii) $\delta_{e_{trim}}$?

   (c) What tends to keep an aircraft flying with $\beta = 0$?

   (d) What is the aileron reversal speed?

   (e) What property does the inertia matrix exhibit when principal axes are employed?

   (f) What undesirable aircraft properties occur when the CG is (i) too far forward or (ii) too far aft?

   (g) What is weathercock stability?

   (h) How can eigenvalues be used to predict aircraft stability?

   (i) How can an aircraft be operated successfully with an unstable spiral mode?

   (j) Following a step elevator input, what is a typical aircraft angle of attack response (i) in the first few seconds, (ii) in the following 10 minutes?

2. Consider an aircraft in level unaccelerated flight with L = W and $C_m = 0$. Assume that propulsive effects can be ignored.

(i) What is the most aft CG location for which $C_{m_\alpha} < 0$?

(ii) What is the minimum tail angle i_t for which $C_{m_0} > 0$?

(iii) Find i_t as a function of CG location h when $\delta_e = 0$.

(iv) Plot the results of (iii) showing the limits imposed by (i) and (ii).

(v) If elevator deflection (for a fixed i_t) is used to compensate for shifts in the CG location, show how the required change of δ_e with CG location h, $\left(\frac{\partial \delta_e}{\partial h}\right)$, depends on C_L.

Given:

$S = 86.875\ m^2$	$V = 123$ m/s
$S_t = 21.375\ m^2$	m = 22,680 kg
$a = 0.088$/deg.	$\rho = 1.225\ kg/m^3$
$a_t = 0.064$/deg.	$h_{n_{wb}} = 0.25$
$\varepsilon_0 = 0.72$ deg.	$\bar{V}_H = 0.6104$
$\frac{\partial \varepsilon}{\partial \alpha} = 0.30$	$C_{m_{ac_{wb}}} = -0.018$

3. Assume that an approximation to the perturbation equations of an aircraft is given by:

$$\dot{\mathbf{x}} = \mathbf{A}\mathbf{x}$$

$$\mathbf{A} = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$$

Express the following in terms of (a, b, c, d):

(i) Find the characteristic equation for the system.

(ii) Find the eigenvalues for the system.

(iii) What condition must apply for there to be oscillatory modes?

(iv) What condition must apply for there to be non-oscillatory modes?

(v) For a given **A** matrix, can there be one oscillatory mode and one non-oscillatory mode?

(vi) What condition must apply for there to be a stable oscillatory mode?

(vii) What condition must apply for there to be a stable non-oscillatory mode?

(viii) Prove that Routh's criterion for static stability (E > 0) applies to this second order system.

(ix) Find the system eigenvectors.

(x) Show that the two columns of adj(λ**I** – **A**) giving the eigenvectors are multiples of one another.