The Flight Environment
1. (Basic) You are the engineer responsible for customizing a new aircraft for local conditions.

(i) Your first task is to generate a chart of temperature, pressure, density ratios for 0 ≤ h ≤ 20 km for the equatorial atmosphere i.e. tropopause at 17 km.

(ii) Taking $T_{SL} = 30^\circ C$, compare with the International Standard Atmosphere (ISA) ($T_{SL} = 15^\circ C$, tropopause at 11 km) and comment on the differences (How significant?)

Advisory: You will need this chart for the exam!

2. (Intermediate – appreciating field operating conditions) Estimate the change in AOA and sideslip for a subsonic transport aircraft caught in the jet stream. Explain your method and document your sources. Compare with wind shear conditions during a microburst.

Static Stability & Control
3. (Intermediate – getting a feel for aircraft parameters) Estimate the wing loading and tail volume ratios for the Boeing 7x7 series of airliners. Comment and compare with the Airbus 3xx series. (Hint: You need to pick a consistent cg location. How sensitive is your result to your choice of cg location?)

4. (Advanced – some theoretical derivation) Consider the aircraft longitudinal trim equations for the wing-tail combination. Show that the trim AOA and tail deflection takes the form $A + B/q_T$ where $q_T$ is the dynamic pressure.

5. (Tricky) We derived in class expressions for the neutral point (aft cg limit) and static margin (stick fixed) for a tail controlled aircraft. How will the expressions change if it were a canard controlled aircraft? How would you modify the stick-elevator mechanism for a canard controlled aircraft to satisfy FAR 23.173(a) requirements?

6. (Advanced & tricky) For the stick-free case, the tail deflection is a function of the trim AOA. Derive the expressions for the neutral point and static margin. Compare your expressions with the stick-fixed case. What is the effect on stability of freeing the tail? (This is the tricky part)
7. (Getting real) For the C130-J shown here, estimate the maximum bank angle needed for OEI flight.

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<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Length</strong></td>
<td>34.37 m</td>
</tr>
<tr>
<td><strong>Height</strong></td>
<td>11.81 m</td>
</tr>
<tr>
<td><strong>Wingspan</strong></td>
<td>40.38 m</td>
</tr>
<tr>
<td><strong>Horizontal tail span</strong></td>
<td>6.05 m</td>
</tr>
<tr>
<td><strong>Power Plant</strong></td>
<td>Four Rolls-Royce AE2100D3 3,460 kW turboprop engines</td>
</tr>
<tr>
<td><strong>MTOW</strong></td>
<td>74,390 kg</td>
</tr>
<tr>
<td><strong>Max cruise speed</strong></td>
<td>660 km/h (355 KTAS)</td>
</tr>
</tbody>
</table>

(Source: Lockheed and Rolls-Royce websites)

**Dynamic Stability Analysis**
8. (Professional - Generating a flight envelope) For an aircraft with thrust vectoring, trimmed, symmetric level flight is governed by:

\[
CL + \frac{T \sin(\alpha+\epsilon)}{(qT)S} = \frac{(W/S)}{qT}
\]
\[
T \cos(\alpha+\epsilon)/(qT)S = CD
\]
\[
Cm = 0
\]

where \( \epsilon \) is the angle between the thrust vector and the X body axis. For a given AOA, obtain the trim altitude and Mach number. The aerodynamic and thrust functions are of the form:

\[
CL = CLO + CL\alpha + CL\delta
\]
\[
CD = CD0 + KCL^2
\]
\[
Cm = Cm0 + Cm\alpha + Cm\delta
\]
\[
T = To + T1h
\]

(Hint: Eliminate T and obtain \( qT \) in terms of \( \alpha \) first)

9. (The 9th and final level!) At one particular trim point, the following data is available:

\[
\rho = 1.225 \text{ kg/m}^3 \quad V = 70.1 \text{ m/s} \quad b = 11.8 \text{ m} \quad S = 49.2 \text{ m}^2
\]
\[
\text{mass} = 15067 \text{ kg} \quad Ix = 32,070 \text{ kg m}^2 \quad Iz = 181,195 \text{ kg m}^2 \quad Ixz = 2,134 \text{ kg m}^2
\]
\[
C_Y = -0.655\beta - 0.0355 \delta a + 0.1240 \delta r
\]
\[
C_l = -0.156\beta - 0.272 pb/(2V) + 0.205 rb/(2V) + 0.0570 \delta a - 0.0009 \delta r
\]
\[
C_n = 0.199\beta - 0.013 pb/(2V) - 1.320 rb/(2V) - 0.0041 \delta a - 0.0720 \delta r
\]

a) Derive the lateral linear small disturbance model \( x' = Ax + Bu \). (Start with the full EOMs)

b) Obtain the eigenvalues for the roll, Dutch roll and spiral modes. (You’ll need Matlab or Mathematica)

c) Assuming this is a class IV aircraft, check if it satisfies MIL-F-8785C, Level 1, Flight Phase A requirements. (Congratulations if you mastered all 9 levels. Smile and pat yourself on the back)