TU-DELFT, FACULTY OF AEROSPACE ENGINEERING

EXAM AE3-S01 AIRCRAFT DESIGN AND OPERATION
PART I QUESTIONS

TUESDAY JANUARY 13TH 2009

14:00-17:00

Remarks

a) Please write down your name and initials on your paper. Fill in the box at the right top corner. Answer all questions and write clown your name on all your pages.

b) This exam consists of a two parts: first, the question part and second, some answer forms with pictures you need for answering certain questions. Please use the answer forms where applicable!

c) Simply answering questions by yes or no will not be honored. The use of a pencil for calculations or writing is not allowed. Do not hand in your draft (take it with you instead).

d) Distribute your time well. First answer the questions you know, keep the more difficult ones for later.

e) As this is an open book exam it is not required to derive or write out equations which are copied from the book: referring to the equation number is sufficient.

Question 1

Sketch in the Figure 1 (see answer forms) the dominant characteristics of modern swept wings for a high subsonic air transport in the low wing configuration:

a) The design pressure distribution at the three indicated typical locations (root, planform break, tip area

b) The ideal spanwise circulation-, lift coefficient and and pitching moment coefficient distribution.

c) The local profiles

Where appropriate the sketches should be supplemented with explanatory text.

Question 2

In Figure 2 (see answer form) the design pressure distribution is given for an airfoil section at a given lift coefficient Cl at Mach 0.72

a) Sketch in the figure the design pressure distribution for an airfoil section with about the same camber line for Mach 0.77 and the same lift coefficient. Make use of the accompanying Cp graph.

b) Will the section be thicker, thinner or remain equally thick? Clarify your answer

Question 3

A preliminary aircraft design study yields the following weights

Operational Empty Weight (OEW)	500 kN
Payload	150 kN
Fuel weight	350 kN (including reserve fuel)
Takeoff weight	1000 kN

After more detailed weight and strength analyses it proved that the OEW will be 50 kN higher. As the design range with the design payload is to be maintained the MTOW must be increased. Fortunately there proved to be some margin in the prediction of the field performance, hence the wing area and engine thrust capability need not to be changed.

Calculate the increase of the MTOW required to recover the design range. You may ignore additional weight increments due to the increased MTOW and the effect of the increased MTOW on the climb performance.

Question 4

a) What requirements are imposed on the inlet of a turbofan engine of a high subsonic aircraft in order to obtain optimal aircraft performance and a maximum net efficiency of the engine?

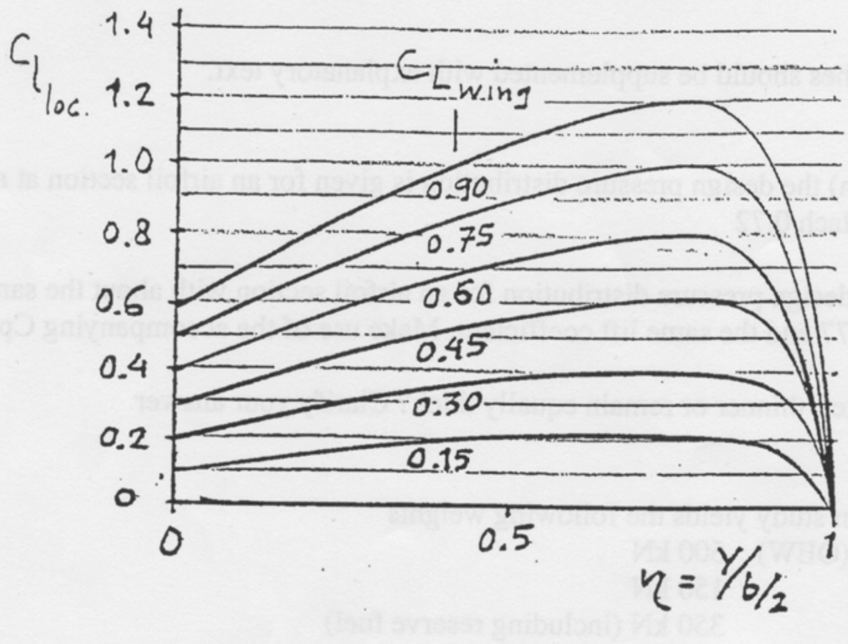
b) Sketch the streamtube of the engine inlet flow for high and low mass flow ratios and indicate areas where flow conditions may be critical for proper engine operation and acceptable nacelle drag

c) Explain the differences in aerodynamics between a wing mounted and a rear fuselage mounted engine installation

d) Why is a diffuser required at the intake between the throat and the fan face?

Question 5

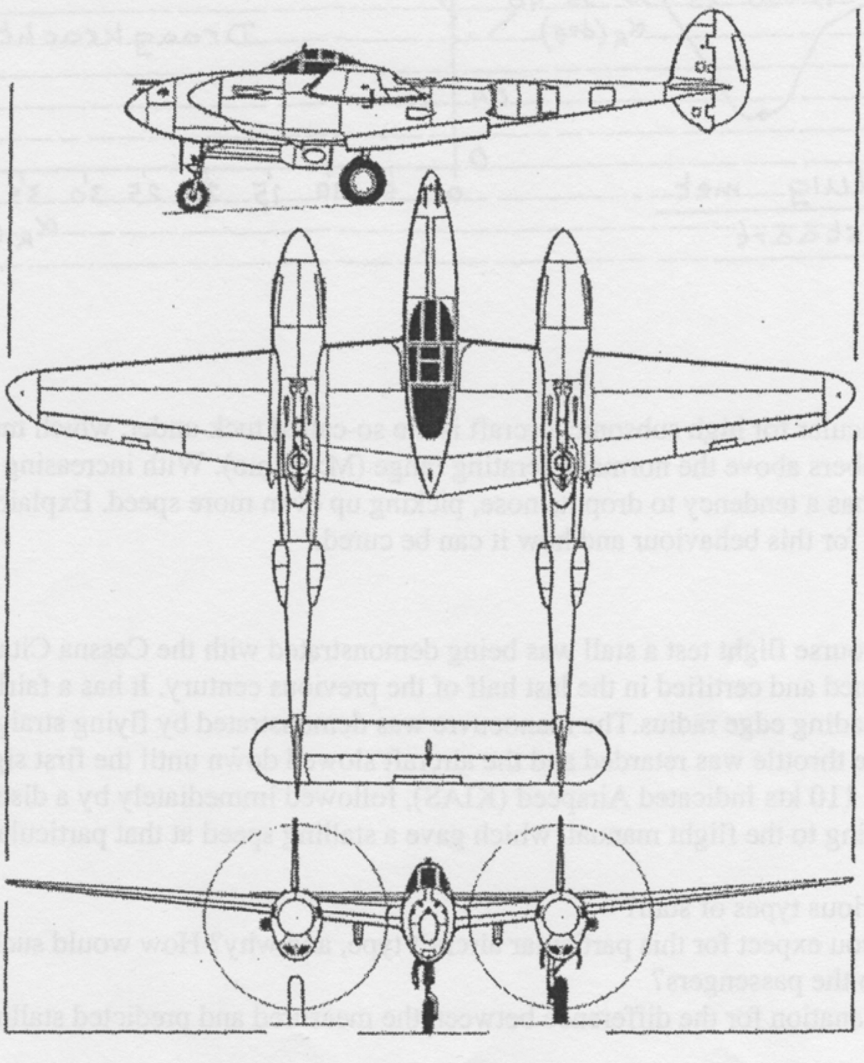
A swept wing has 45° sweepback at the ¼ chordline. It has a finite aspect ratio, no camber and no twist. The calculated spanwise distribution of the Cl has been plotted in the following figure for different wing lift coefficients.The used airfoil section perpendicular to the ¼ chord line has a Clmax of 1.6. At which wing lift coefficient do you predict that local separations will occur, and indicate where on the wing the first flow separations will occur. You may ignore effects of a thickening of the boundary layer from root to tip.



Question 6

The Lockheed Lightning in the following picture was for its time a high powered combat aircraft. It was relatively unique in the sense that the propellers rotated in opposite directions.

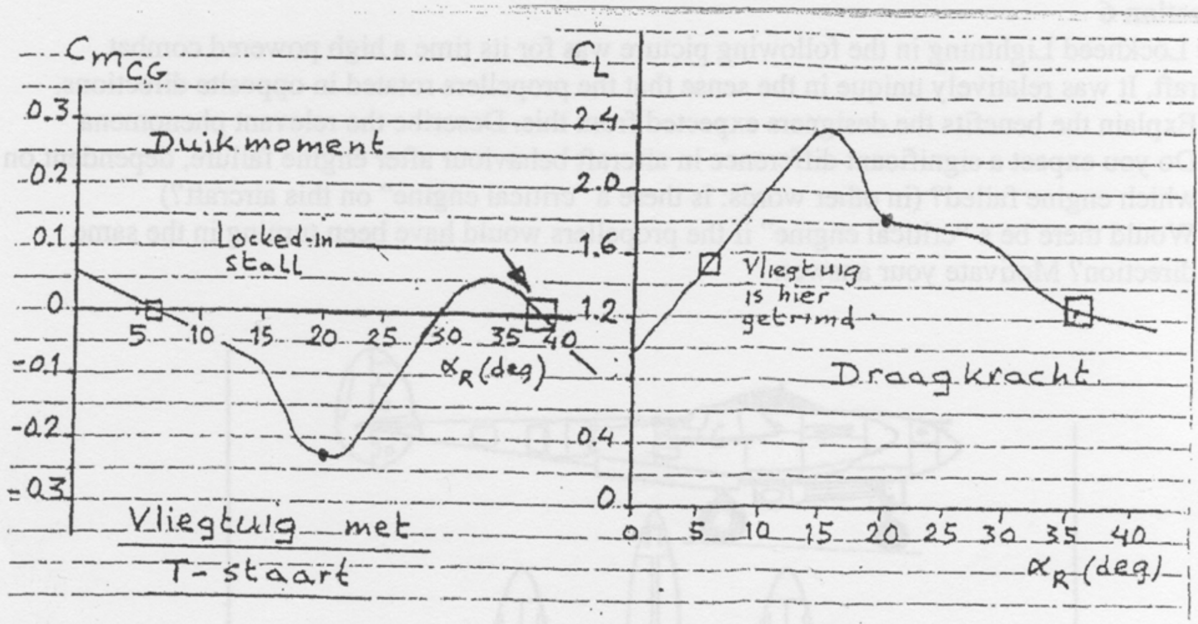
a) Explain the benefits the designers expected from this. Describe the relevant phenomena
b) Do you expect a significant difference in aircraft behaviour after engine failure, dependent on which engine failed? (in other words: is there a "critical engine" on this aircraft?)
c) Would there be a "critical engine" if the propellers would have been turning in the same direction? Motivate your answer.



Question 7

The following figure shows the moment curve CM vs αR and the lift curve CL vs αR of a typical T-tail aircraft with flaps deflected. The aircraft is trimmed at αR = 6° and CL=1.55

a) Describe what happens when -due to a gust- αR increases suddenly to 20°.
b) Explain what will happen if, possibly due to a combination of turbulence and hard manoeuvring of the aircraft, αR increases to >30°. Will the aircraft arrive by itself to a stable situation, and if so, what is then the αR?
c) Explain this phenomena briefly

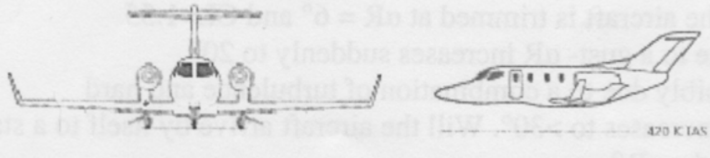


Question 8
A phenomenon particular for high subsonic aircraft is the so-called tuck under, which may appear at Mach numbers above the normal operating range (M> Mmo). With increasing Mach number the aircraft has a tendency to drop its nose, picking up even more speed. Explain the aerodynamic causes for this behaviour and how it can be cured.

Question 9
During the second-course flight test a stall was being demonstrated with the Cessna Citation II. This type was designed and certified in the last half of the previous century. It has a fairly thin wing with a small leading edge radius.The manoeuvre was demonstrated by flying straight and level, after which the throttle was retarded and the aircraft slowed down until the first signs of a stall were evident at 110 kts Indicated Airspeed (KIAS), followed immediately by a distinct stall. This was not according to the flight manual, which gave a stalling speed at that particular weight of 99 KIAS.

a) What are the various types of stall?
b) Which type do you expect for this particular aircraft type, and why? How would such a stall manifest itself to the passengers?
c) What is the explanation for the difference between the measured and predicted stalling speed?

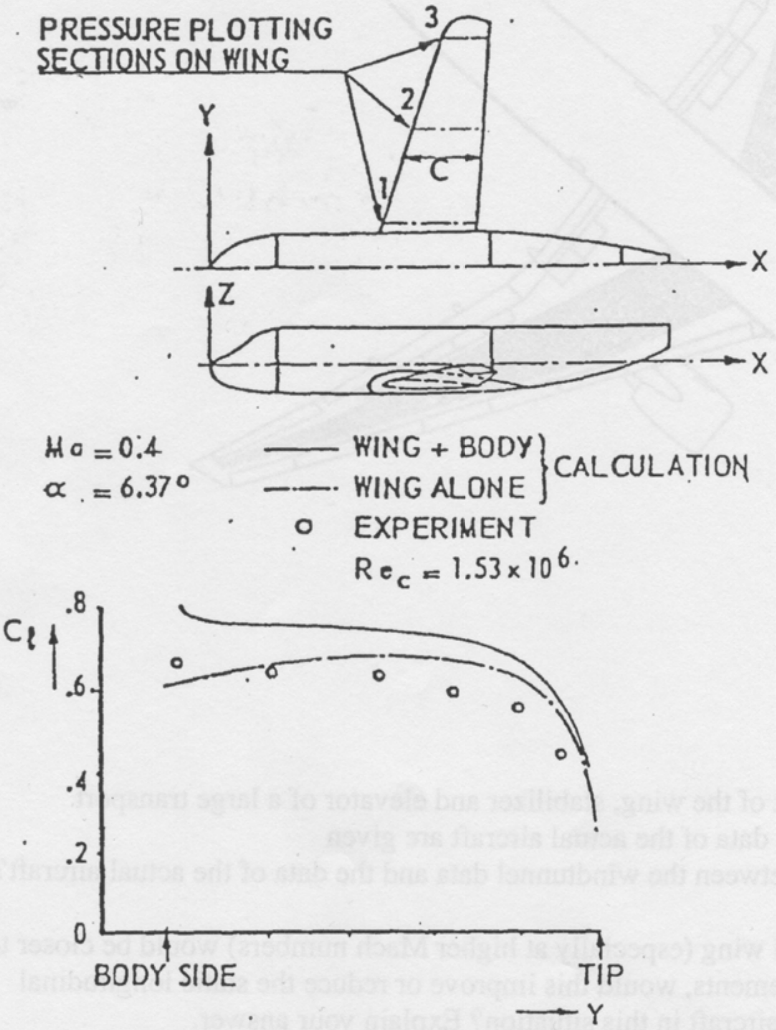
Question 10



In the picture above you see the Honda Jet currently under development.
Chapter 43 of your textbook contains a list of relevant paragraphs of the different subparts of CS.25.

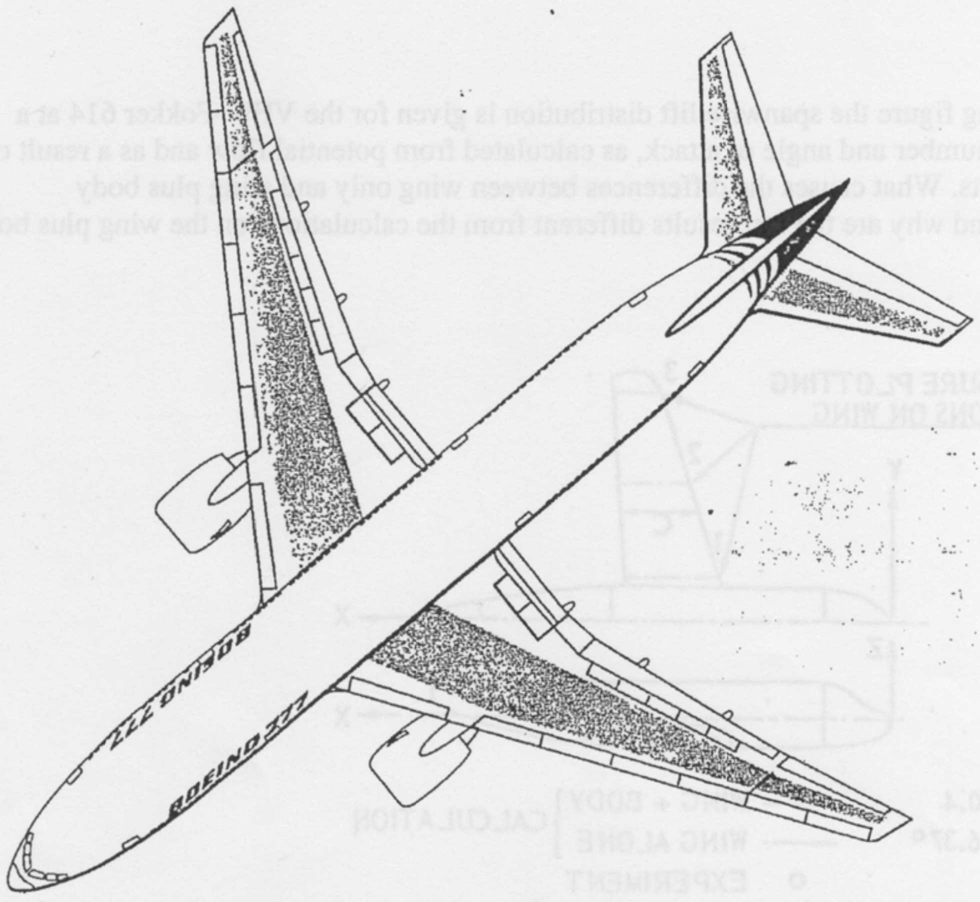
a) Which paragraphs would require increased/extensive “proof of compliance” efforts concerning the aerodynamic design of this aircraft? Name at least 2 and explain your answer.
b) Do you think also new paragraphs would be necessary? If yes, define one additional paragraph, if not, explain why you think the current set of paragraphs is sufficient.
c) Which are the main areas of uncertainty in this design? Name at least 2 and explain your answer.

Question 11
In the following figure the spanwise lift distribution is given for the VFW-Fokker 614 at a certain Mach number and angle of attack, as calculated from potential flow and as a result of windtunnel tests. What causes the differences between wing only and wing plus body calculations, and why are the test results different from the calculations on the wing plus body model?



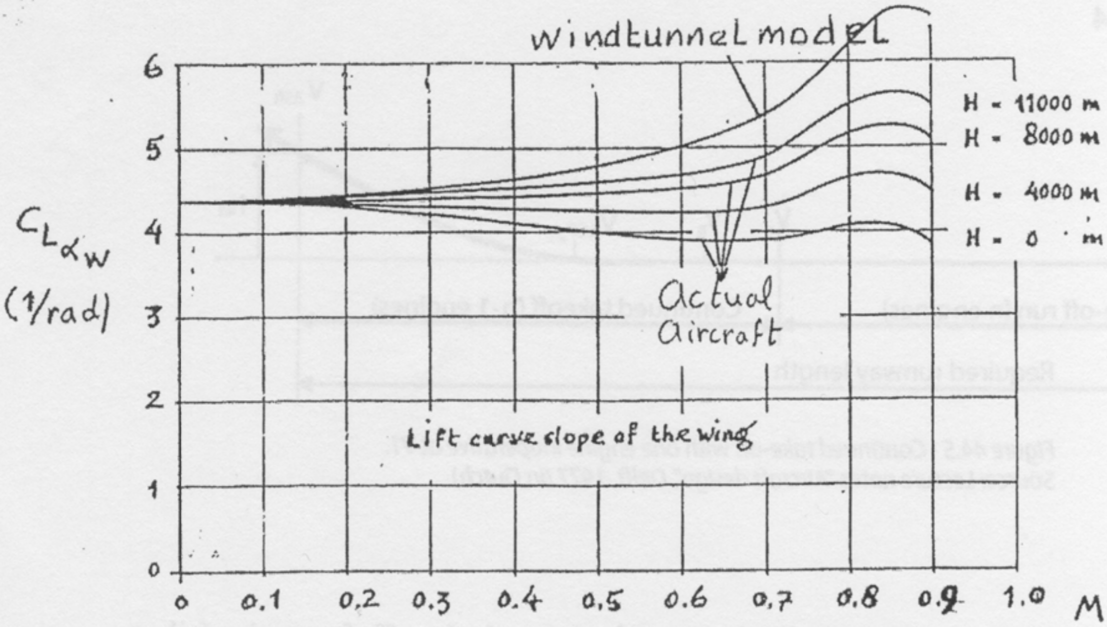
SPANWISE LIFT DISTRIBUTION FOR A TYPICAL, SHORT RANGE, SUBSONIC TRANSPORT CONFIGURATION. (VFW-Fo 614)

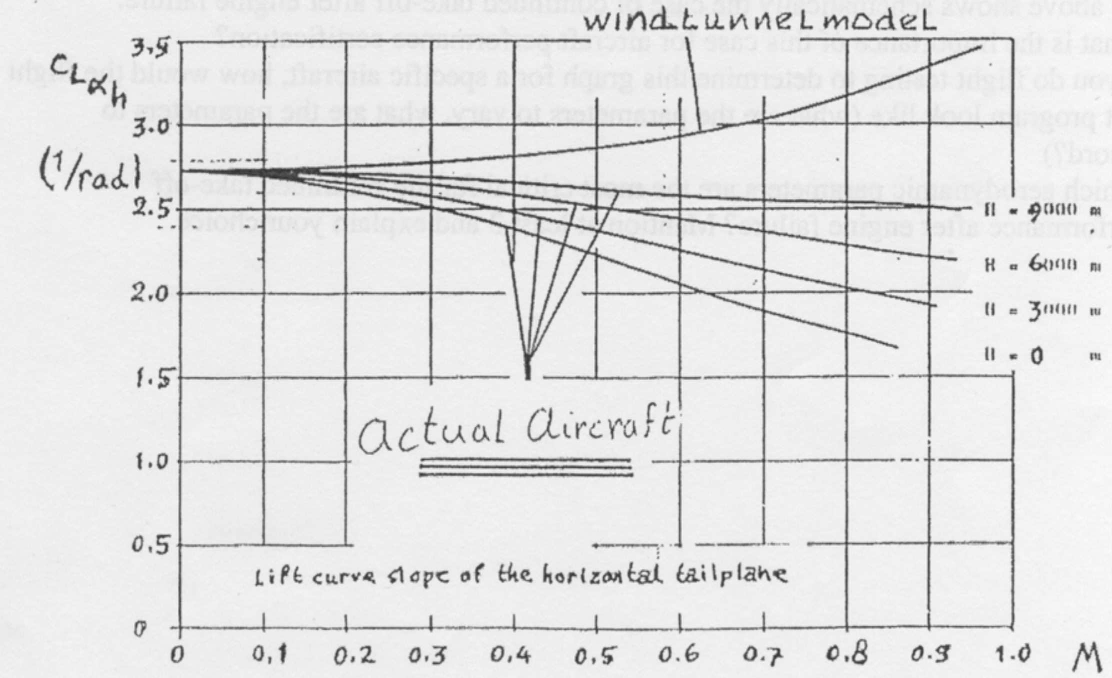
Question 12
In the following figure the top view is given of the Boeing 777. Give at least 2 reasons why the spoiler panels have been split in several surfaces.

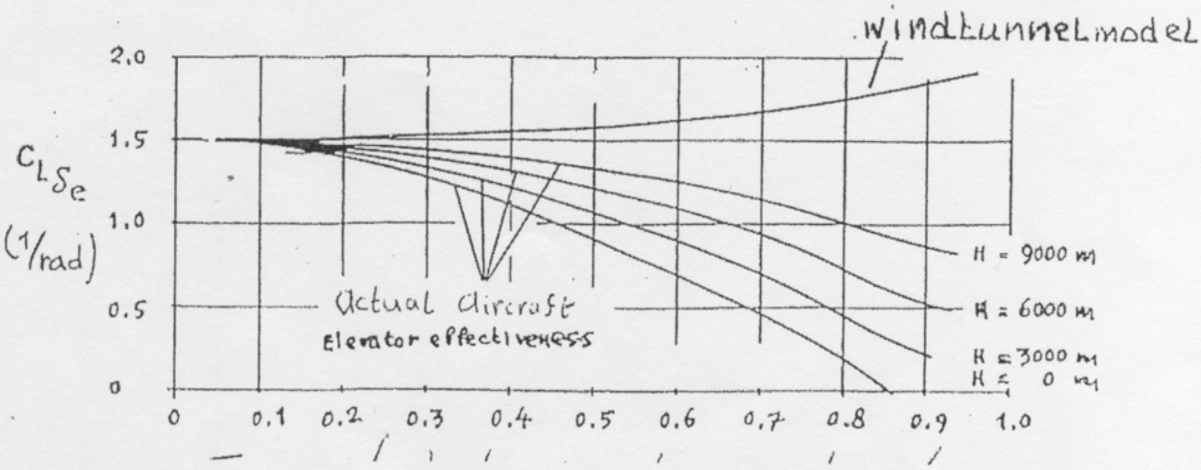


Question 13
This Figure shows the lift gradient of the wing, stabilizer and elevator of a large transport aircraft. Both windtunnel data and data of the actual aircraft are given

a) What causes the differences between the windtunnel data and the data of the actual aircraft? Give your arguments
b) If the lift gradient of the actual wing (especially at higher Mach numbers) would be closer to that of the windtunnel measurements, would this improve or reduce the static longitudinal stability (neutral point) of the aircraft in this situation? Explain your answer.


windtunnel model
H - 11000 m
H - 8000 m
H - 4000 m
H - 0 m
Actual Aircraft
Lift curve slope of the wing
$C_{L\alpha_W}$ (1/rad)
M


windtunnel model
H = 9000 m
H = 6000 m
H = 3000 m
H = 0 m
Actual Aircraft
Lift curve slope of the horizontal tailplane
$C_{L\alpha_h}$ (1/rad)
M


windtunnel model
H = 9000 m
H = 6000 m
H = 3000 m
H = 0 m
Actual Aircraft
Elevator effectiveness
$C_{L\delta_e}$ (1/rad)

Question 14

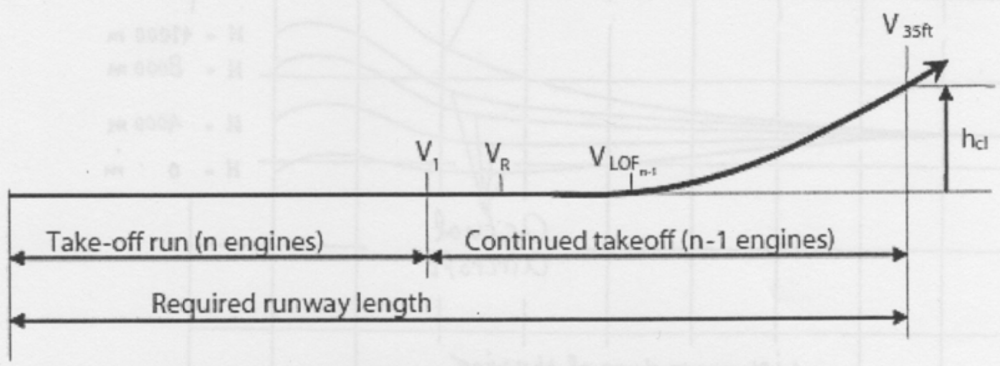


Figure 44.5 - Continued take-off with one engine inoperative at V1.
Source: Lecture notes "Aircraft design", Delft, 1977 (in Dutch)

The figure above shows schematically the case of continued take-off after engine failure.

1) What is the importance of this case for aircraft performance certification?
2) If you do flight testing to determine this graph for a specific aircraft, how would the flight test program look like (what are the parameters to vary, what are the parameters to record?)
3) Which aerodynamic parameters are the most critical for the continued take-off performance after engine failure? Mention at least 3 and explain your choice.