DEPARTMENT FAHRZEUGTECHNIK UND FLUGZEUGBAU

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Flugzeugentwurf / Aircraft Design SS 2015

Date: 11.07.2015

Duration of examination: 180 minutes

Last Name:	First Name:
Matrikelnummer:	
Points: of a maximum of 73 points.	Grade:

1. Part

35 points, 70 minutes, closed books

1.1) Please translate to German.

Please write clearly! Unreadable text will not harvest points!

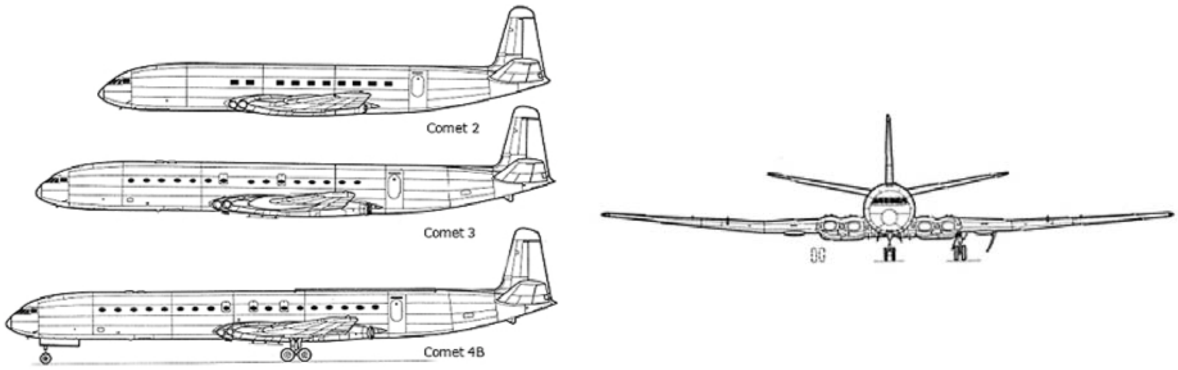
1. aeroplane
2. airplane
3. aircraft
4. flying wing
5. aerodynamic center
6. payload
7. sweep
8. taper
9. dihedral
10. twist
11. camber
12. bending

1.2) Please translate to English.

Please write clearly! Unreadable text will not harvest points!

1. Flugzeugentwurf
2. Machzahl
3. Fahrwerk
4. Leitwerk
5. Höhenleitwerk
6. Seitenleitwerk
7. Rückenflosse
8. Anstellwinkel
9. Einstellwinkel
10. Hängewinkel
11. Steigwinkel
12. V-Winkel

1.3) Shown is a de Havilland DH 106 Comet. It was the first production commercial jet. Developed and manufactured by de Havilland at its Hatfield Aerodrome, Hertfordshire – the location of our long term ERASMUS partner university, the University of Hertfordshire.



Source: http://www.zoggavia.com

Please name 4 technical characteristics and for each characteristic at least one advantage and one disadvantage!

1.4) What is the value of a typical zero-lift drag coefficient for a passenger aircraft? Calculate its drag coefficient at minimum drag speed!

1.5) What is the value of a typical ratio between wetted area and wing area of a passenger aircraft? Estimate the maximum glide ratio $(L/D)_{max}$ for such an aircraft with an aspect ratio of 6!

1.6) What is the value of a typical equivalent skin friction coefficient for a passenger aircraft? And what is again the value of a typical ratio between wetted area and wing area of a passenger aircraft? Calculate the value for the zero lift drag coefficient of a passenger aircraft from these numbers!

1.7) What is the minimum speed (with respect to stall speed) at take-off of a business jet?

1.8) What is the minimum speed (with respect to stall speed) at approach of a business jet?

1.9) What is the ratio of the maximum lift coefficient and the actual lift coefficient at minimum approach speed of a business jet?

1.10) Please write down the „First Law of Aircraft Design“ from which you can calculate the maximum take-off mass m_{MTO} from payload m_{PL} ? Everything else equal: How much more is the maximum take-off mass m_{MTO} if the payload m_{PL} doubles?

1.11) How is the tail volume coefficient defined for a vertical tail? Explain how to obtain the vertical tail surface area from the vertical tail volume coefficient! Explain how to get each parameter needed!

1.12) Assume you investigated the one class seat layout of many passenger aircraft in order to find out the value of the ratio between the number of rows n_R and the number of seats abreast n_{SA}. Assume you found the ratio of $n_R/n_{SA} = 4$. Determine n_{SA} for an aircraft seating 169 passengers! Explain your choice in light of certification rules CS-25! Write the equation to determine n_{SA} for any ratio n_R/n_{SA} !

1.13) You plan to design a fuselage with circular cross section for minimum zero lift drag. How do you set up your optimization? Select all correct options!

A The task is to minimize zero lift drag per cabin volume
B The task is to minimize zero lift drag per cabin area
C The task is to minimize zero lift drag per frontal area
D The task is to minimize zero lift drag per total area of the passenger doors
E The task is to minimize zero lift drag per total area of the cargo doors

1.14) You want to design a cabin with 6 seats abreast. What are your options with respect to the number of aisles? Discuss!

1.15) In which sequence is it best to allocate wing parameters in a hand calculation? Input parameter is the cruise Mach number. Select all correct options!

A First: wing vertical position, sweep, dihedral angle. Then: taper ratio, thickness ratio.
B First: wing vertical position, sweep. Then: taper ratio, dihedral angle, thickness ratio.
C First: sweep. Then: wing vertical position, taper ratio, dihedral angle, thickness ratio.
D First: dihedral angle, sweep. Then: taper ratio, wing vertical position, thickness ratio.

1.16) Please order these Mach numbers with respect to increasing flight speed: (typical) cruise Mach number, MMO, critical Mach number, MD, M_{DD}! Discuss your sequence if necessary!

1.17) Name three parameters that you would change, if asked to reduce wing drag in transonic flight at given cruise Mach number! Would you increase or decrease each of these parameters?

1.18) You need to carry much fuel for your long range aircraft. How would you change (increase or decrease) each parameter listed (if you are still free to decide): Wing area, wing aspect ratio, wing sweep, taper ratio, relative thickness of the wing? Discuss your selection if necessary!

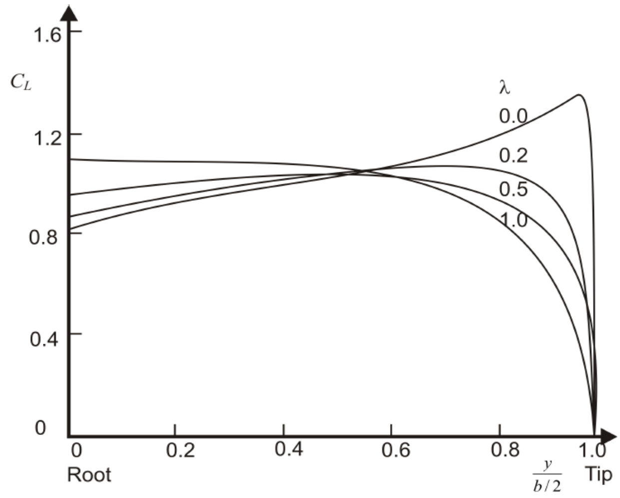
1.19) Many wings have a kink and are hence formed by two trapezia. Why is this necessary? State aerodynamic benefits (if any)!

1.20) Explain why wing twist may help to optimize the lift distribution in the design point, but causes more drag in off-design situations!

1.21) For a quick design of a main landing gear: How many tons from the maximum take-off mass do you allocate to each of the main wheels? Or in other words: How many wheels do we need on the main gear?

1.22) How is the concrete of a runway more likely to fail due to a certain large aircraft with given mass: if each main landing gear leg has two wheels or if each main landing gear leg has four wheels?

1.23) At a certain angle of attack, a wing would "theoretically" show the distribution of the lift coefficient as given in the diagram that gives actually the behavior of four wings with different taper ratios. Here "theoretically" means that the diagram was produced with an aerodynamic code that can not predict stall. You plan to use an airfoil with a maximum lift coefficient of 1.2. Which of the wings stalls at the given angle of attack and where does it stall? Which wing(s) will produce most lift? Discuss!



1.24) What is the ultimate design goal (objective function) for commercial aircraft?

Questions from the Lecture Series

1.25) Has metal a chance in aircraft design in the future, or will aircraft continue to be dominated by composite materials? Explain your answer!

1.26) ICAO puts aircraft in various classes. What are the span limitations (at airports) for aircraft in Class C and D respectively?

1.27) What is the advantage of a propeller driven aircraft compared to a propfan with respect to engine integration certification?

1.28) How efficient are winglets?
- A Winglets have no effect on the aerodynamic efficiency of an aircraft.
- B Winglets 1 m high have roughly the same effect as a horizontal wing span increase of 0.5 m on each wing tip.
- C Vertical winglets have the same aerodynamic effect as a horizontal wing span extension of the same size.

1.29) What amount of fuel saving can be achieved with a "Smart Turboprop" (as described in the evening lecture) against the jet powered A320?

1.30) Explain how it is possible to achieve "double digit" (%) savings in fuel consumption of passenger aircraft just based on parameter choice in aircraft design without any introduction of new technologies!

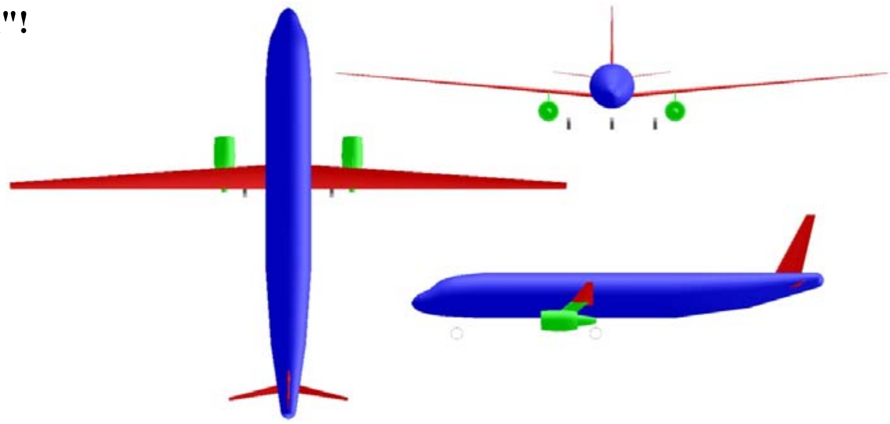
2. Part

Name:___________________________________

110 minutes, 38 points, open books and laptop

Task 2.1 (18 points)

Design "The Rebel"!



These are the requirements for the aircraft:

- Payload: 180 people on board with baggage. 93 kg per person. Additional cargo: 2516 kg.
- Range 1510 NM at a cruise Mach number $M_{CR} = 0.55$ (payload as above, with reserves as given in FAR Part 121, domestic reserves, distance to alternate: 200 NM)
- Take-off field length $s_{TOFL} \leq$ 2700 m (ISA, MSL at maximum take-off mass)
- Landing field length $s_{LFL} \leq 2700$ m (ISA, MSL at maximum landing mass)
- Furthermore the requirements from FAR Part 25 §121(b) (2. Segment) and FAR Part 25 §121(d) (missed approach) shall be met

For your calculation

- The factor k_{APP} for approach, k_L for landing and k_{TO} for take off should be selected according to the spread sheet and to the lecture notes.
- The ratio of maximum landing mass and maximum take-off mass $m_{ML}/m_{MTO} = 0{,}92$
- Maximum lift coefficient of the aircraft in landing configuration $C_{L,max,L} = 3{,}1$
- Maximum lift coefficient of the aircraft in take-off configuration $C_{L,max,TO} = 3{,}1$
- The glide ratio is to be calculated for take-off and landing with $C_{D0} = 0.02$ and Oswald factor $e = 0.5$
- Oswald factor in cruise $e = 0.68$
- Aspect ratio $A = 34.8$
- Calculate the maximum glide ratio in cruise, E_{max} with $e = 0.68$ und $S_{wet} / S_W = 9.1$
- The ratio of cruise speed and speed for minimum drag is set to the optimum value:

  $V_{CR} / V_{md} = \sqrt[4]{3}$. **Design point is the intersection from take-off and landing line!!!**
- The operating empty mass ratio is $m_{OE} / m_{MTO} = 0.59$.
- The by-pass ratio (BPR) of this generic engine is close to $\mu = 15.5$; their thrust specific fuel consumption for cruise and loiter is assumed to be $c = 10{,}3$ mg/(Ns).

- Use these values as Mission-Segment Fuel Fractions: Engine start: 1.00; Taxi: 0.997; Take-off: 0.994; Climb: 0.994; Descent: 0.994; Landing: 0.994.

Results to task 2.1

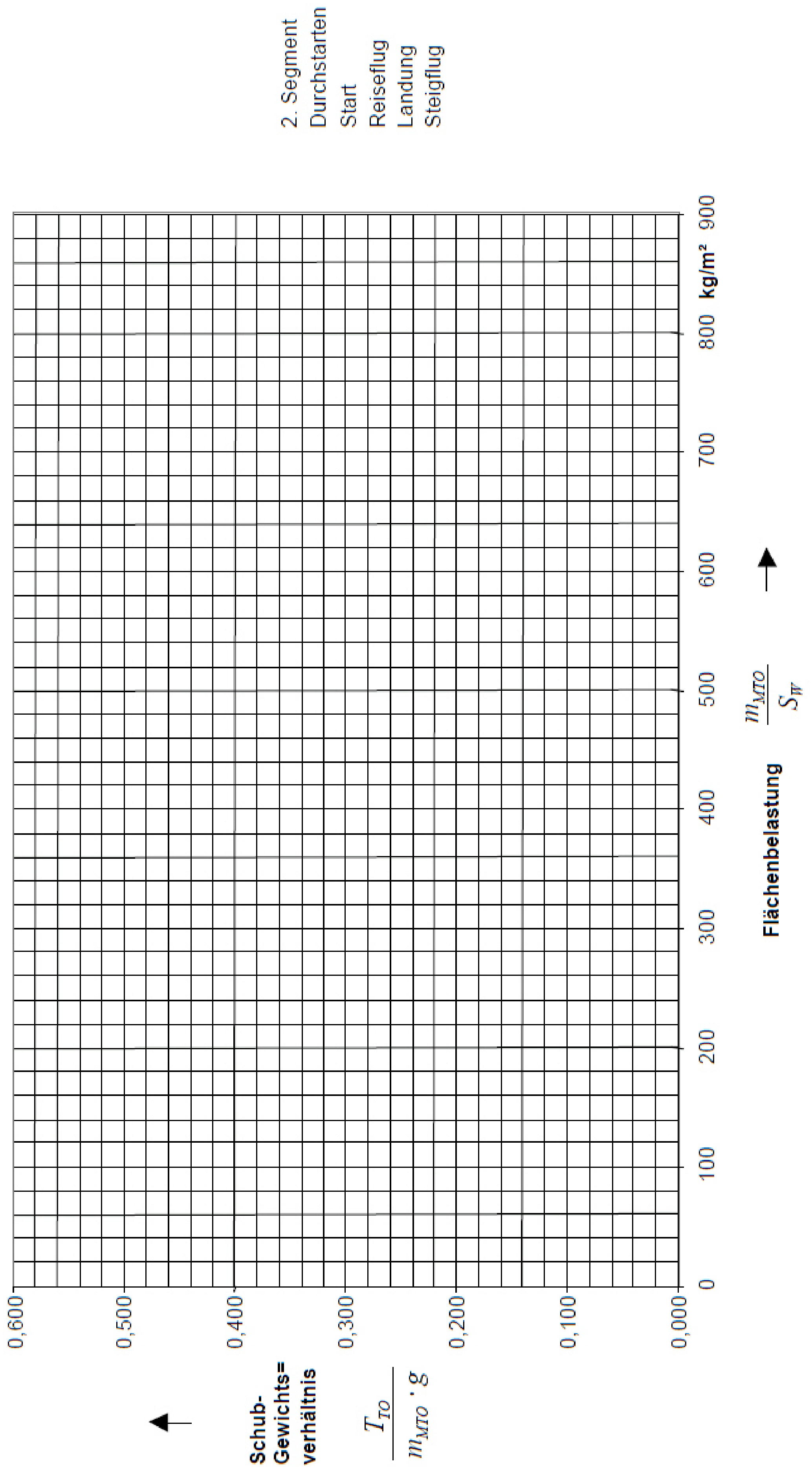
Please insert your results here! Do not forget the units!

- Wing loading from landing field length:
- Thrust to weight ratio from take-off field length (at wing loading from landing):
- Glide Ratio in 2. Segment:
- Glide Ratio during missed approach maneuver:
- Thrust to weight ratio from climb requirement in 2. Segment:
- Thrust to weight ratio from climb requirement during missed approach maneuver:
- V_{CR}/V_{md}:
- Design point
    - Thrust to weight ratio :
    - Wing loading:
- Cruise altitude:
- maximum take-off mass:
- maximum landing mass:
- wing area:
- thrust of one engine **in N**:
- required tank volume **in m³**:

Draw the matching chart (you need to change the scale of the axis for the wing loading!) and **indicate the design point in the matching chart**!

Label your line in the legend on the right of page of the chart. Here is your translation:

Durchstarten	=	missed approach	Start	=	take-off
Reiseflug	=	cruise	Landing	=	landing
2. Segment	=	2. Segment	Steigflug	=	climb (not required here)


2. Segment
Durchstarten
Start
Reiseflug
Landung
Steigflug
Schub-
Gewichts=
verhältnis
$\frac{T_{TO}}{m_{MTO} \cdot g}$
0,600
0,500
0,400
0,300
0,200
0,100
0,000
0
100
200
300
400
500
600
700
800
900
kg/m²
Flächenbelastung
$\frac{m_{MTO}}{S_W}$

Task 2.2 (4 points)

A wing is designed for low manufacturing costs with $\lambda = 1$ (no taper). Calculate the sweep angle for an approximate elliptical wing loading! Calculate the dihedral angle for a high wing aircraft with this sweep angle!

NIŢĂ, Mihaela Florentina: *Contributions to Aircraft Preliminary Design and Optimization*. München : Verlag Dr. Hut, 2013. - URL: http://OPerA.ProfScholz.de --- Equations (2.25) and (2.80), take “own values” from table.

Task 2.3 (8 points)

Calculate the Oswald Factor e for a jet in cruise! The unsept wing with $\lambda = 0.25$ has an aspect ratio of 35. Fuselage diameter is 4 m and wing span is 49 m. Cruise Mach number: 0.55.

NIŢĂ, Mihaela Florentina: *Contributions to Aircraft Preliminary Design and Optimization*. München : Verlag Dr. Hut, 2013. - URL: http://OPerA.ProfScholz.de --- Equation (2.30a) and related equations.

Task 2.4 (8 points)

Find the slenderness ratio (also called fineness ratio) l_F/d_F of the fuselage of a passenger aircraft that yields the lowest zero lift drag of its fuselage per unit of cabin area (assumed to be proportional to an area equal to fuselage length multiplied by fuselage diameter)! Use the equations to estimate

- the fuselage wetted area for fuselages with a cylindrical middle section from TORENBEEK and
- the form factor for fuselages from DATCOM as given in the lecture notes.

You may want to plot the function that gives some relative zero lift drag as a function of slenderness ratio. You may want to work with your computer.