HAW HAMBURG

DEPARTMENT FAHRZEUGTECHNIK UND FLUGZEUGBAU

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Flugzeugentwurf / Aircraft Design SS 2019

Date: 04.07.2019

Duration of examination: 180 minutes

Last Name: Matrikelnummer:		First Name:
Points:	of a maximum of 74 points.	Grade:

1. Part

40 points, 60 minutes, closed books

1.1) Please translate to German.

Please write clearly! Unreadable text causes subtraction of points!

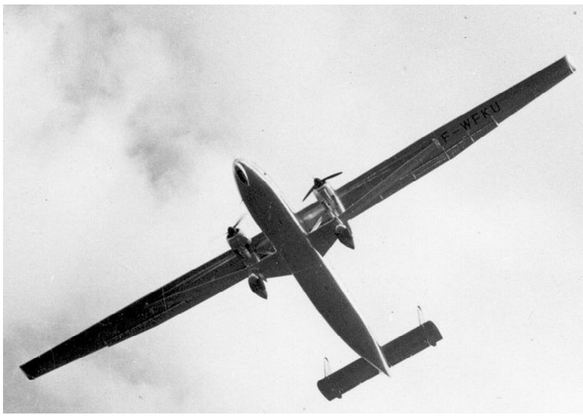
1. aircraft
2. aircraft design
3. trailing edge angle
4. camber
5. thickness
6. leading edge
7. take-off distance
8. second segment
9. T-tail
10. rudder
11. vertical tail
12. landing gear

1.2) Please translate to English.

Please write clearly! Unreadable text causes subtraction of points!

1. Flügel
2. Höhenleitwerk
3. V-Leitwerk
4. Spannweite
5. Hinterkante
6. Gang
7. Triebwerk
8. Triebwerksstil
9. Fenster
10. Landung
11. 2. Segment
12. Durchstarten

1.3) Shown is the aircraft Hurel Dubois HD 31. Please name 4 technical characteristics and for each characteristic at least one advantage and one disadvantage!



1.4) Sketch a diagram showing take-off ground roll distance, take-off distance, 1st Segment, 2nd Segment. How are these segments defined? When does the 4th Segment end?

1.5) How is the landing distance defined?

1.6) What is a typical value for the Oswald factor during a) cruise and b) take-off and landing?

1.7) Please give the „First Law of Aircraft Design“, from which you can calculate the maximum take-off mass m_{MTO} from payload m_{PL} ?

1.8) How can we find out from the „First Law of Aircraft Design“ that a design is infeasible?

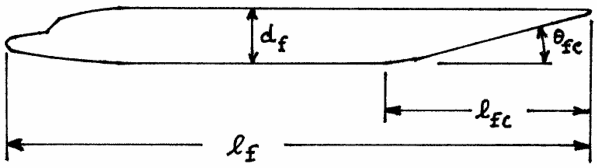
1.9) What is a typical value for the maximum lift coefficient in landing configuration for passenger transports?

1.10) What is a typical length for the cockpit of passenger transport aircraft? Estimate the cabin length of a six-abreast aircraft seating 120 passengers!

1.11) Determine together with results from 1.10 the length of the aircraft! The aircraft may have a fineness ratio $l_F/d_F = 8$. *You may need to derive an equation to find the result!*

1.12) a) A container has a volume V. The container extends in aircraft x direction (aft) a distance x. Write down the equation to calculate the cross sectional area of the container. b) The volume of the cargo V_C, baggage V_B, and overhead stowage V_{OS} is known. The aircraft overall length l_F is also known. Calculate the minimum cross sectional area of the cargo compartment.

1.13) Why does a fuselage taper in at the tail from the bottom (as shown) and not from the top or from both sides?



1.14) How is the tail volume coefficient defined for horizontal and vertical tail?

1.15) In which diagram do we find "potato curves"?

1.16) Passenger aircraft are usually built to a given span according to ICAO/FAA classes. Assume that during design the wing area can be reduced by 50%. How does this change the aspect ratio? How does this change the tank volume? *Calculate two values!*

1.17) What reduces induced drag more a) a 1 m high winglet or b) a span increase of 1 m at each wing tip? *Explain your answer!*

1.18) For high lift design, we assume the maximum lift coefficient of the wing to be 10% higher than that of the aircraft. Why?
1.19) For high lift design, we account any additional lift coefficient comming from flaps only with 95%. Why?
1.20) What is the amount of static margin usually considered for the design of a jet transport?
1.21) In which direction do nose landing gears extend? They extend down and ... (*Finish the sentence!*)
1.22) Name the equation, from which the zero-lift drag coefficient C_{D0} can be calculated from the equivalent skin friction coefficient C_{fe}!
1.23) Explain the "Cutoff Reynolds Number"!
1.24) "Shevell's Curve" is used for wave drag estimation. What is the trigonometric function used to represent "Shevell's Curve"?
1.25) How is the Mach number called beyond which wave drag is initially very small but present?
1.26) What is this equation used for? What value is used for M_{comp}?

$$k_{e,M} = a_e \left(\frac{M}{M_{comp}} - 1 \right)^{b_e} + c_e$$

1.27) Direct Operating Costs (DOC) consist of various const elements. Please name them!

$$C_{DOC} = C_{DEP} + C_{INT} + C_{INS} + C_F + C_M + C_C + C_{FEE}$$

1.28) What are "seat-mile costs"?

Questions from the Evening Lectures

1.29) What does the Concorde flight engineer demonstrate in the picture with his right hand?

1.30) When Concorde flies from Europe to the USA, a sun rise can be seen in the West! Why?
1.31) Technology readiness levels (TRLs) are a method for estimating the maturity of technologies. How many levels are defined?
1.32) MAMs can be used in aircraft to reduce low-frequency engine noise in the cabin. What does MAM stand for?
1.33) Write down the equation to calculate the range of a battery-electric aircraft!
1.34) Who is the entrepreneur behind Space X? Who is the entrepreneur behind Blue Origin?
1.35) We have a new buzz word: "disruptive technology". What does it mean?

2. Part

Name:___________________________________

120 minutes, 43 points, open books and laptop

Task 2.1 (18 points)

Redesign the short-medium range aircraft *Airbus A220-300* !

These are the requirements for the aircraft:

- Payload: 160 passengers with baggage. Additional payload: 3831 kg.
- Range 3350 NM at a cruise Mach number M_{CR} = 0.78 (payload as above, with reserves as given in FAR Part 121 domestic, distance to alternate: 200 NM)
- Take-off field length $s_{TOFL} \leq$ 1890 m (ISA, MSL)
- Landing field length $s_{LFL} \leq$ 1509 m (ISA, MSL)
- 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.
- Maximum lift coefficient of the aircraft in landing configuration $C_{L,max,L}$= 3.24
- Maximum lift coefficient of the aircraft in take-off configuration $C_{L,max,TO}$ = 2.55
- The glide ratio is to be calculated for take-off and landing with C_{D0} = 0.02 and Oswald factor e = 0.7
- Oswald factor in cruise e = 0.85
- Aspect ratio A = 10.97
- Maximum glide ratio in cruise, E_{max} = 22.8
- The ratio of cruise speed and speed for minimum drag V_{CR}/V_{md} has to be found such that a favorable matching chart is obtained. Find V_{CR}/V_{md} with to digits after the decimal place
- The ratio of maximum landing mass and maximum take-off mass m_{ML}/m_{MTO} = 0.85
- The operating empty weight ratio is m_{OE} / m_{MTO} = 0.531
- The by-pass ratio (BPR) of the two Pratt & Whitney PW1500G engines is μ = 12; their thrust specific fuel consumption for cruise and loiter is c = 11.2 mg/(Ns).
- Use these values as Mission-Segment Fuel Fractions: Engine start: 0.990; Taxi: 0.990; Take-off: 0.995; Climb: 0.980; Descent: 0.990; Landing: 0.992.

Results to task 2.1

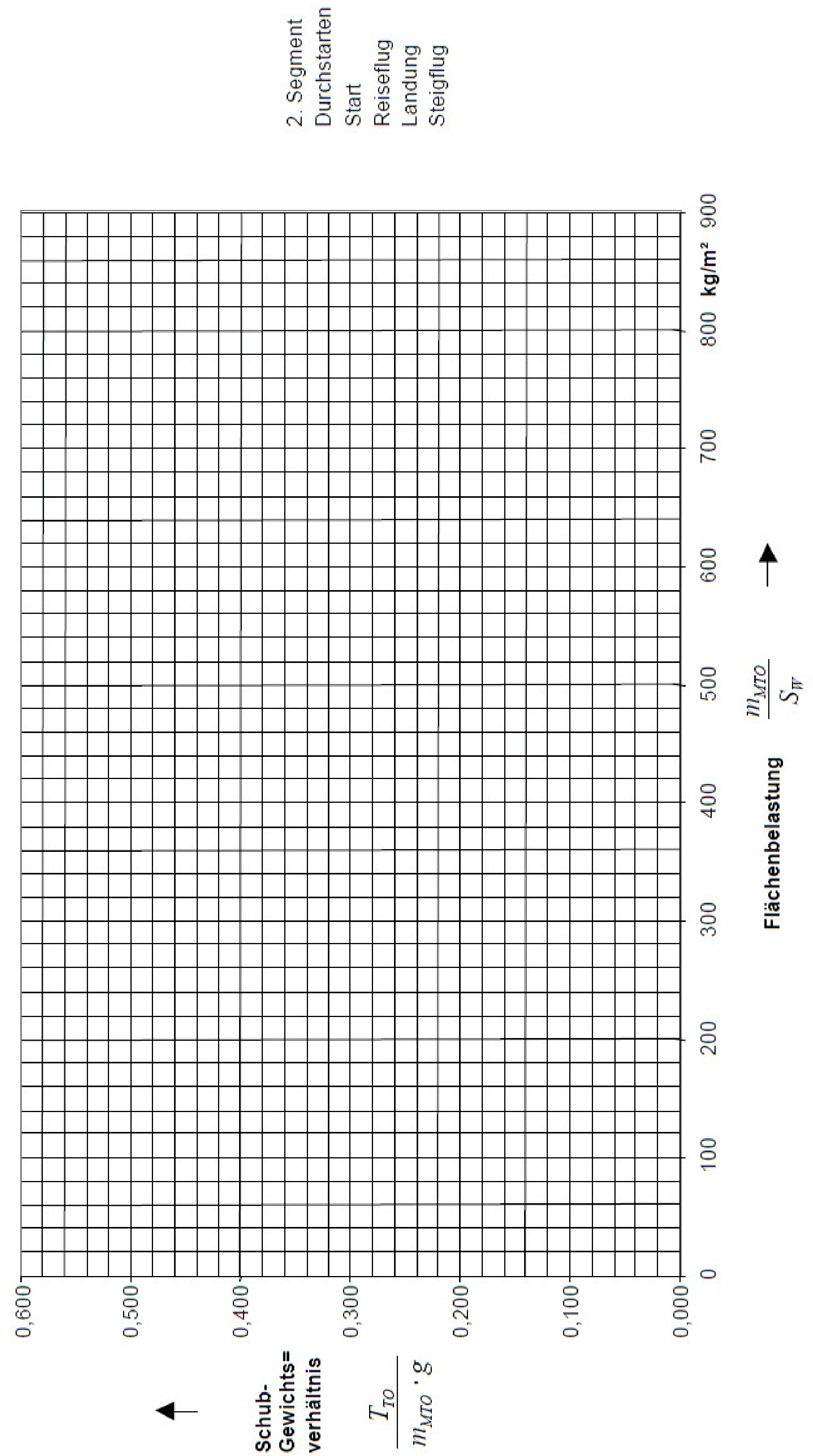
Please insert your results here! Do not forget the units!

- 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 lb**:
- required tank volume **in m^3**:

Draw the matching chart and **indicate the design point in the matching chart**!

Label your line in the legend on the right of page 6. Here is your translation:

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


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

Task 2.2 (2 points)
Based on Task 2.1, calculate the wing span! Comment on your result!

Task 2.3 (5 points)
Just consider the two requirements take-off field and landing field length. Consider also the two equations from aircraft sizing from LOFTIN to calculate thrust to weight ratio from take-off field length and wing loading from landing field length.

a) Derive an equation for thrust to weight ratio from *both* these equations!
b) What kind of thrust to weight ratio do we desire?
c) What kind of mass ratio: landing mass over take-off mass do we desire?
d) If landing field length is fixed, what take-off field length do we desire?
So, what value seems logical for the take-off field length?
e) What about the ratio of maximum lift coefficients in landing and take-off?

Task 2.4 (4 points)
Compare the wing mass of two large passenger transport aircraft having wings with different aspect ratios. Use TORENBEEK's equation and ignore the term with b_{ref} (see below) by setting it equal to one. Assume a rectangular wing ($\lambda = 1$). A relative thickness was selected for the wing and will not change as the aspect ratio changes. The wing area will not change. Assume also the wing loading does not change. Derive an equation for the ratio of the wing mass of the two wings! What happens to the wing mass as the aspect ratio is increased?

Do not consider this term in the equation: $\left(1+\sqrt{\frac{b_{ref}}{b_s}}\right)$

Task 2.5 (5 points)
An aircraft has these parameters:

Maximum take-off mass:	73000 kg
Relative operating empty mass:	0.5
Relative fuel mass:	0.25

a) Calculate the operating empty mass! Calculate the fuel mass!
b) Calculate the payload!
c) The operating empty mass is now increased by 1 kg (some weight growth during design). *This is the "local mass increase".* Calculate the resulting maximum take-off mass! *You may need to iterate. Note, the relative fuel mass is unchanged, but the relative operating empty mass is slightly increased due to the extra 1 kg.* Calculate the increase in maximum take-off mass! *This is the "global mass increase".*
d) Divide the "global mass increase" by the "local mass increase" of 1 kg! How is this ratio called?