VEL TECH
Dr.RR & Dr.SR
TECHNICAL UNIVERSITY
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Avadi, Chennai
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Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

DEPARTMENT AUTOMOTIVE AND AERONAUTICAL ENGINEERING

Prof. Dr.-Ing. Dieter Scholz, MSME

Short Course Aircraft Design at Vel Tech University

Date: 19.02.2016

Total duration: 180 min., duration Part 1: 80 min., total points: 69.

Name:		
Registration number:		
Points part 1:	of 38 points.	Result of examination:

Hints:

- Part 1 of the examination is without notes, books, and computer. All calculations are meant to be quick hand calculations. You may simplify e.g. g = 10 m/s.
- Please return the task sheet.
- If nothing else is specified, an answer to a question yields one point.

Part 1

1.1) Translate „aircraft“ to German!

1.2) Translate „Flugzeugentwurf“ to English!

1.3) What is the task of aircraft design in the practical sense?

1.4) What is the task of aircraft design in an abstract sense?

1.5) List all requirements that should be known when the aircraft design of a passenger aircraft is started! Hint: Requirements are from cruise performance and airport performance.

1.6) Name 5 key design parameters that come out from preliminary sizing!

1.7) Preliminary sizing is listed as step 5 in the design sequence as proposed in the Short Course. Please name at least 5 of the next design steps leading to „aircraft evaluation / operating costs / DOC“!

1.8) What does it mean “to shrink” or “to stretch” an aircraft in the context of an aircraft family?

1.9) The payload-range-diagram: Why is the maximum payload limited by Maximum Zero Fuel Weight (MZFW)?

1.10) The payload-range-diagram: Please explain the term “ferry range”!

1.11) The payload-range-diagram: Is it possible to go maximum range with maximum payload? Explain your answer!

1.12) An aircraft is designed for 9 passengers and a maximum take-off mass of 5700 kg. How are the applicable European certification rules called? How are the applicable US certification rules called?

1.13) How is an “unconventional configuration” defined?

1.14) a) Draw any possible matching chart (from aircraft preliminary sizing) with its 5 constraints and name the axis! b) Highlight the area in the chart that yields feasible designs! c) What are the two rules for finding an optimum design point? (3 points)

1.15) An aircraft carries 10 t of payload. Its relative fuel mass is 0.4 and its relative operating empty mass is 0.5. Calculate the maximum take-off mass! Show your calculation!

1.16) An aircraft has a thrust-to-weight ratio of 0.25. What is (roughly) its relative operating empty mass? Show your calculation!

1.17) How is the mission of a civil aircraft defined with respect to its flight phases?

1.18) What is a typical thrust specific fuel consumption of a turbo fan engine?

1.19) Give the equation to calculate the mission segment fuel fraction for the cruise phase! Hint: It is derived from the Breguet range equation.

1.20) An aircraft has a maximum take-off mass of 100 t and a wing loading of 1000 kg/m². Calculate the wing area!

1.21) An aircraft has a maximum take-off mass of 100 t and a thrust to weight ratio of 0.25. Calculate the take-off thrust of the aircraft (all engines together)!

1.22) A cabin is designed for 100 passengers. How many seats abreast do you propose? Explain your answer!

1.23) A cabin is designed for 8-abreast seating. 4 benches with two seats each of 40 in width are used. How many aisles (of 20 in width) are required? What is the cabin width (including a gap to the side wall)?

1.24) A cabin is designed for 240 passengers. The design follows the details given in the question above. What is (roughly) its length?

1.25) An aircraft has a cabin length of 20 m and a fuselage diameter of 4 m. Calculate the fuselage length!

1.26) What is (aerodynamically) the optimum taper ratio for an unswept wing?

1.27) An aircraft has a high swept wing. What dihedral angle do you expect? (Give an approximate number.)

1.28) How does the tank volume change (increase or decrease) if …

a) the wing area is increased?

b) the relative thickness of the wing is increased?

c) the aspect ratio is increased?

1.29) Why do we need a higher maximum lift coefficient for the wing than for the whole aircraft?

1.30) Consider a typical passenger aircraft with engines on the wing. Fuselage length is 60 m, mean aerodynamic chord is 3 m. Wing area is 70 m². Calculate the area of the horizontal tail!

1.31) A long range aircraft has a maximum take-off mass of 360 t. How many main wheels do you propose on the main landing gear? Explain your answer!

1.32) A typical passenger aircraft has an aspect ratio of 6. Estimate its maximum glide ratio E_{max}! Show your calculations!

1.33) Direct Operating Costs (DOC) are calculated from a maximum of 7 cost elements. Name at least 5 of them!

1.34) Give typical values for a jet transport for C_{D0}, e, E_{max}, and equivalent skin friction coefficient, C_{fe}!

1.35) Give typical values for a jet transport for $C_{L,max,L}$, $C_{L,max,TO}$ / $C_{L,max,L}$, A, and φ_{25} of the wing!

Part 2

Name: ________________________________

100 minutes, 31 points, open books and laptop

Task 2.1 (17 points)

A slow flying low wing short range jet with 4 engines is designed for short take-off and landing.

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} = 0.66 (payload as above, with reserves as given in FAR Part 121, domestic reserves, distance to alternate: 200 NM)
- Take-off field length $s_{TOFL} \leq$ 1000 m (ISA, MSL at maximum take-off mass)
- Landing field length $s_{LFL} \leq$ 1000 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} = 0.9
- 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 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
- Calculate the maximum glide ratio in cruise, E_{max} with e = 0.85 und S_{wet} / S_W = 6.1
- The ratio of cruise speed and speed for minimum drag is set to the optimum value: V_{md} / V = 1.3161 .
- The operating empty mass ratio is m_{OE} / m_{MTO} = 0.5 .
- The by-pass ratio (BPR) of the engine is μ = 10; its thrust specific fuel consumption for cruise and loiter is assumed to be c = 14 mg/(Ns). The aircraft has 4 engines.
- Use these values as Mission-Segment Fuel Fractions: Engine start: 1.00; Taxi: 0.997; Takeoff: 0.994; Climb: 0.994; Descent: 0.994; Landing: 0.994.

Task 2.2 (6 points)

For an aircraft with data as **given** in Task 2.1 calculate from equations as given in the short course:

a) sweep angle of the wing
b) average relative thickness of the wing (use the simple equation which is a function of M_{CR} only)
c) relative thickness of the wing at the wing root
d) relative thickness of the wing at the wing tip
e) optimum taper ratio
f) dihedral angle

Task 2.3 (2 points)

Calculate the tire diameter for an aircraft with maximum take-off mass of 360 t and 12 wheels and equivalent ground pressure p^* = 30 t/m² and a tire width to diameter ratio of 0.4 .

Task 2.4 (6 points)

Calculate based on the AEA DOC method for short range aircraft (AEA 1989a):

a) the depreciation C_{DEP} for an aircraft with a total price if 100,000,000 US$.
b) the number of flights per year if the standard DOC flight has a flight time of 1 hour,
c) the depreciation for one flight and one passenger (assume 150 passenger on each flight).

Results to task 2.1

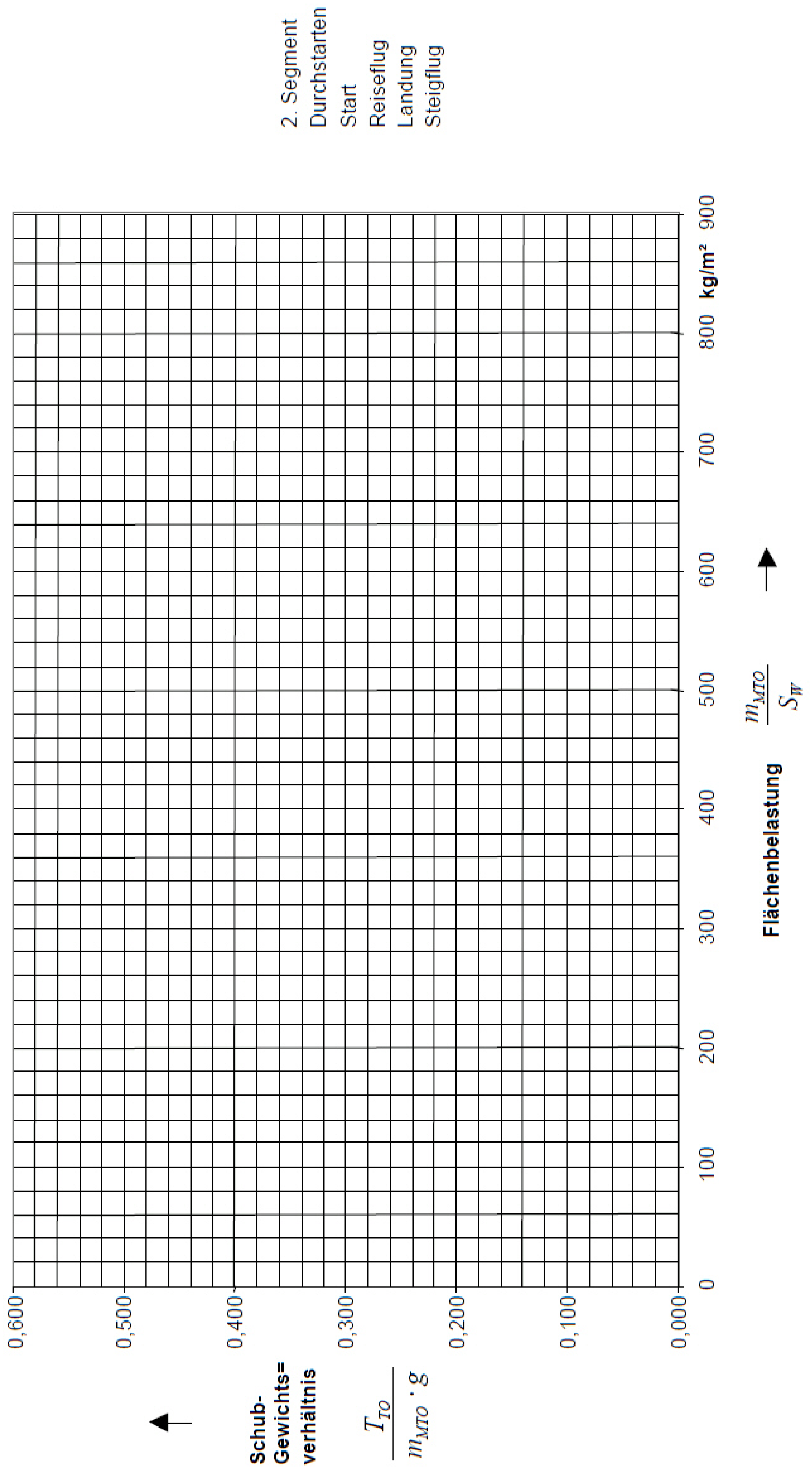
Please insert your results here! Do not forget the units!

- 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:
- 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 and also **indicate the design point in the matching chart**!

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

2. Segment	=	2. Segment
Durchstarten	=	missed approach
Start	=	take-off
Reiseflug	=	cruise
Landing	=	landing
Steigflug	=	climb (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
900
kg/m²
Schub-
Gewichts=
verhältnis
$\frac{T_{TO}}{m_{MTO} \cdot g}$
Flächenbelastung
$\frac{m_{MTO}}{S_W}$