HAW HAMBURG

DEPARTMENT OF AUTOMOTIVE AND AERONAUTICAL ENGINEERING

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Flugzeugentwurf / Aircraft Design SS 2022

Date: 12.07.2022

Duration of examination: 180 minutes

Last Name:		First Name:
Matrikelnummer:		
Points:	of a maximum of 90 points.	Grade:

1. Part

41 points, 60 minutes, closed books

1.1) Please translate to German.

Please write clearly! Unreadable text causes subtraction of points!

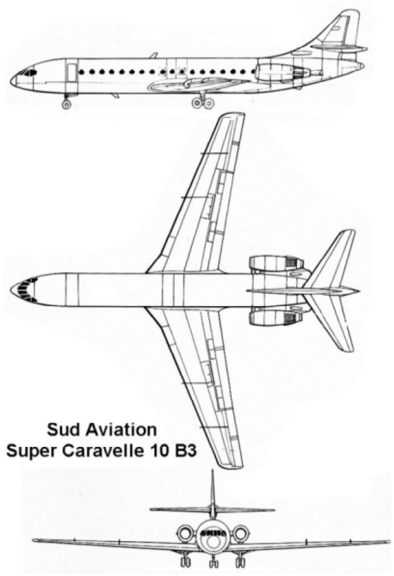
1. aeroplane
2. aircraft
3. friction
4. fuselage
5. aileron
6. empennage
7. canard (aircraft)
8. aviation
9. altitude
10. aerodrome
11. flight
12. landing

1.2) Please translate to English.

Please write clearly! Unreadable text causes subtraction of points!

1. Flugzeugentwurf
2. Machzahl
3. Krüger-Klappe
4. Prandtl-Staurohr
5. Flettner-Klappe
6. Grenzschicht
7. Rückenflosse
8. Schütteln
9. Spreizklappe
10. V-Form
11. Verdichtungsstoß
12. Vorflügel

1.3) Shown is a Sud Aviation Caravelle. The Caravelle established the aft-mounted engine, clean-wing design. First flight was already in 1955. This aircraft is still using a modified version of the old NACA 65-212 airfoil.



Source:
http://www.smikesworld.dk/smworld/my_models/aviation_list_aircraft_schematics.html

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

1.4) What is a typical value for the Oswald factor during take-off and landing (i.e. with flaps extended)?

1.5) An aircraft A is designed for a payload $m_{PL,A}$. Based on the same technology, an aircraft B has to be designed with $m_{PL,B} = 2\ m_{PL,A}$. Calculate $m_{MTO,B} / m_{MTO,A}$ or comment!

1.6) An aircraft A is designed for a range R_A . Based on the same technology, an aircraft B has to be designed with $R_B = 2\ R_A$. Calculate $m_{MTO,B} / m_{MTO,A}$ or comment!

1.7) What is the safety factor used to define the landing field length?

1.8) What is the safety factor used to define the take-off field length, considering the case of all engines operative, AEO?

1.9) A missed approach climb is pretty tough. Why? What are the two facts that help to make the missed approach climb bearable? *You may want to refer to the equation to calculate thrust-to-weight ratio for missed approach.*

1.10) An aircraft has to be designed for 225 passengers. For the future a stretch is envisaged. Decide on the number of seats abreast in economy class. How many aisles does the aircraft need? How many flight attendants does the aircraft need?

1.11) How many passengers (maximum number) can the "ZEROe" aircraft carry based on its door arrangement? *See picture!*

1.12) What are the ditching requirements with respect to sill (German: Schwelle) height?

1.13) How do we calculate (in a first step), whether an aircraft is designed correctly to satisfy ditching requirements or not?

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

1.15) What is a (standard) dorsal fin? *Please add a little drawing to your answer!* What is the purpose of a dorsal fin?

1.16) What is a "round edge dorsal fin"? *Please add a little drawing to your answer!*

1.17) What are the design alternatives (*name two*) to a dorsal fin?

1.18) A particular Airbus passenger aircraft may have a cruise Mach number of 0.82. What is its drag divergence Mach number? What is its wave drag coefficient at that Mach number? How is the Mach number called at which the wave drag is just reduced to zero?

1.19) For what purpose is dihedral used in aircraft design?

1.20) As a rule of thumb: How many kilogram maximum take-off mass can be carried by one main landing gear wheel?

1.21) What is meant by "rigid pavement" and "flexible pavement"?

1.22) What do we learn from Swedish crispbread (Swedish: knäckebröd / hårdbröd) when it comes to main landing gear design for rigid pavement?

1.23) An aircraft has a tire pressure of 200 psi. What is the pressure exerted on the ground?

1.24) Describe the minimum-effort path (from the lecture) to zero-lift drag coefficient estimation!

1.25) Which parameter can be minimized in preliminary aircraft sizing to approximate minimization of Direct Operating Costs (DOC)? Explain why!

Questions from the Evening Lectures

1.26) We look at Effective Radiative Forcing, ERF from kerosene combustion. What is the share of a) CO2, b) contrails and resulting contrail cirrus, c) consequences of NOx emissions?

1.27) Less than 12% of the flights cause ____% of the contrail forcing! *Complete!*

1.28) Contrails are warming during the ____, whereas contrails may be cooling during the _____ .

1.29) We look at Effective Radiative Forcing, ERF from hydrogen combustion. What is the share of a) CO2-emissions, b) none-CO2 emissions?

1.30) Which statement(s) is(are) correct? *Several (or even all) statements may be correct.*

a) Kerosene consists of hydrocarbons (CxHy), hydrogen is H2. This means that the combustion of hydrogen produces 2.56 times as much water and thus potentially more (sometimes warming) clouds could form (with the same amount of energy).

b) In principle, there are no contrails or cloud formation in an aircraft operated with LH2, because hydrogen aircraft are characterized by "zero emissions" (ZEROe).

c) Hydrogen burns without soot and thus without condensation nuclei. The water from the combustion condenses on the few condensation nuclei in the atmosphere. Assumption: If the radius of the ice crystals (imagined as a sphere) is 3.33 times as large as a result, then the volume is 3.33 . 3.33. 3.33 = 37 times as large and the cross-section of the sphere is 3.33. 3.33 = 11 times as large. Together, the sky is covered by only 11/37 . 2.56 = 76% compared to burning kerosene (with the same amount of energy).

1.31) Sustainable aviation fuel (SAF) differs chemically little from conventional kerosene. How should SAF become sustainable? What effects on global warming remain?

1.32) The aircraft recycling market matures. Publication of guidance material for best practices are published by associations like ....

1.33) How can an aircraft or an aircraft component be given a second life? *Name six ways!*

1.34) Due to the requirements of flight mechanics, the mass of the aircraft and the center of gravity must be kept within specified limits. Why does the position of the center of gravity have to be constantly known during loading (on the ground)? What danger is there?

1.35) Name the four cargo compartments, which are distinguished on the A330 Freighter!

1.36) An Airbus A330 can be equipped with 4 tanks. Outer wing tank, inner wing tank, center tank. What is the name of the fourth tank? Where is this tank located?

Name:_____________________

2. Part

49 points, 120 minutes, open books

Task 2.1 (18 points)

Redesign of an *Airbus A320* !

These are the requirements for the aircraft:

- Payload: 180 passengers with baggage (93 kg per passenger). Additional payload: 2516 kg.
- Range 1510 NM at a cruise Mach number $M_{CR} = 0.76$ (payload as above, with international reserves as given in FAR Part 121, with 5% extra fuel on distance flown, distance to alternate: 200 NM)
- Take-off field length $s_{TOFL} \leq$ 1768 m (ISA, MSL)
- Landing field length $s_{LFL} \leq 1448$ 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 $C_{L,max,L}= 3.41$
- Maximum lift coefficient of the aircraft in take-off configuration $C_{L,max,TO} = 2.58$
- 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 $e = 0.783$
- Aspect ratio $A = 9.5$
- Maximum glide ratio in cruise, $E_{max} = 17.48$
- 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 two digits after the decimal place
- The ratio of maximum landing mass and maximum take-off mass $m_{ML}/m_{MTO} = 0.878$
- The operating empty weight ratio is $m_{OE} / m_{MTO} = 0.56$
- The by-pass ratio (BPR) of the two CFM56 engines is $\mu = 6$; their thrust specific fuel consumption for cruise and loiter is $c = 16.5$ mg/(Ns).
- Use these values as Mission-Segment Fuel Fractions: Engine start: 0.997; Taxi: 0.993; Take-off: 0.993; Climb: 0.993; Descent: 0.993; Landing: 0.993.

Results for task 2.1

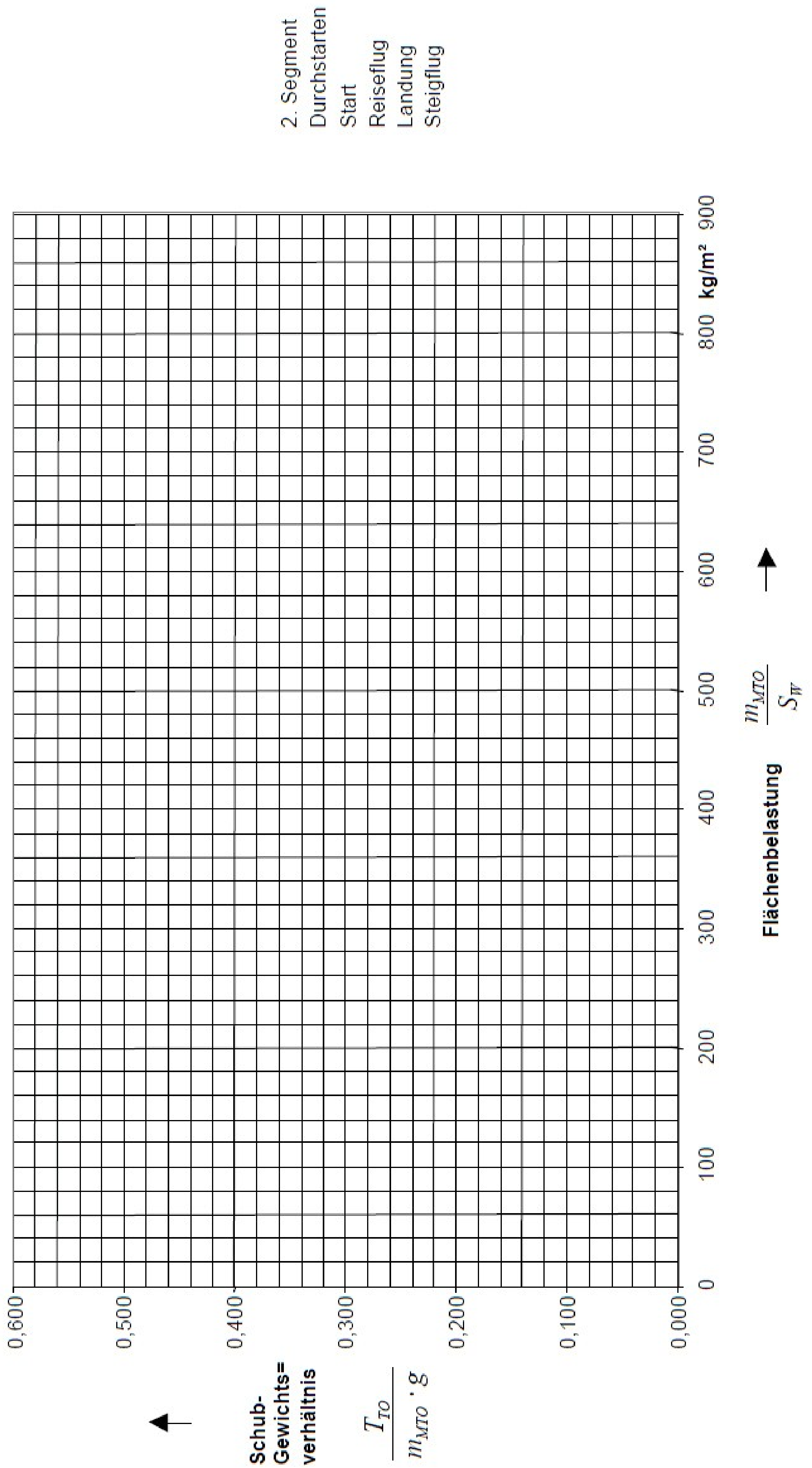
Please insert your results here! Do not forget the units!

- 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 the matching chart. 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
0 100 200 300 400 500 600 700 800 900
kg/m²
Flächenbelastung
$\frac{m_{MTO}}{S_W}$
0,000 0,100 0,200 0,300 0,400 0,500 0,600
Schub-Gewichts=verhältnis
$\frac{T_{TO}}{m_{MTO} \cdot g}$

Task 2.2 (17 points)

Design of a *Hydrogen (LH2) Airbus A320* !

- Maximum glide ratio in cruise is now: E_{max} = 16.92 (reduced by 3.2%).
- Relative operating empty mass is increased by 14%.
- The specific fuel consumption for cruise and loiter is based on the original one of c = 16.5 mg/(Ns). Calculate the specific fuel consumption of the hydrogen engine from the explanation below.

Hydrogen has 2.87 times more energy per mass (kg) than kerosene (Jet A-1). The inverse means that its mass is 1/2.87 = 0.35 or only 35% for the same energy. This also means that the Specific Fuel Consumption, c (SFC) of a hydrogen jet engine is only 35% of that known from a kerosene jet engine. This has nothing to do with the propulsive or thermodynamic efficiency of the engine. It is just a result from the gravimetric energy of the fuel in use.

Hints for your design:

- Mass ratio, landing - take-off: 0.95
- Max. lift coefficient, take-off: 2.45
- 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 two digits after the decimal place.

Results to task 2.2

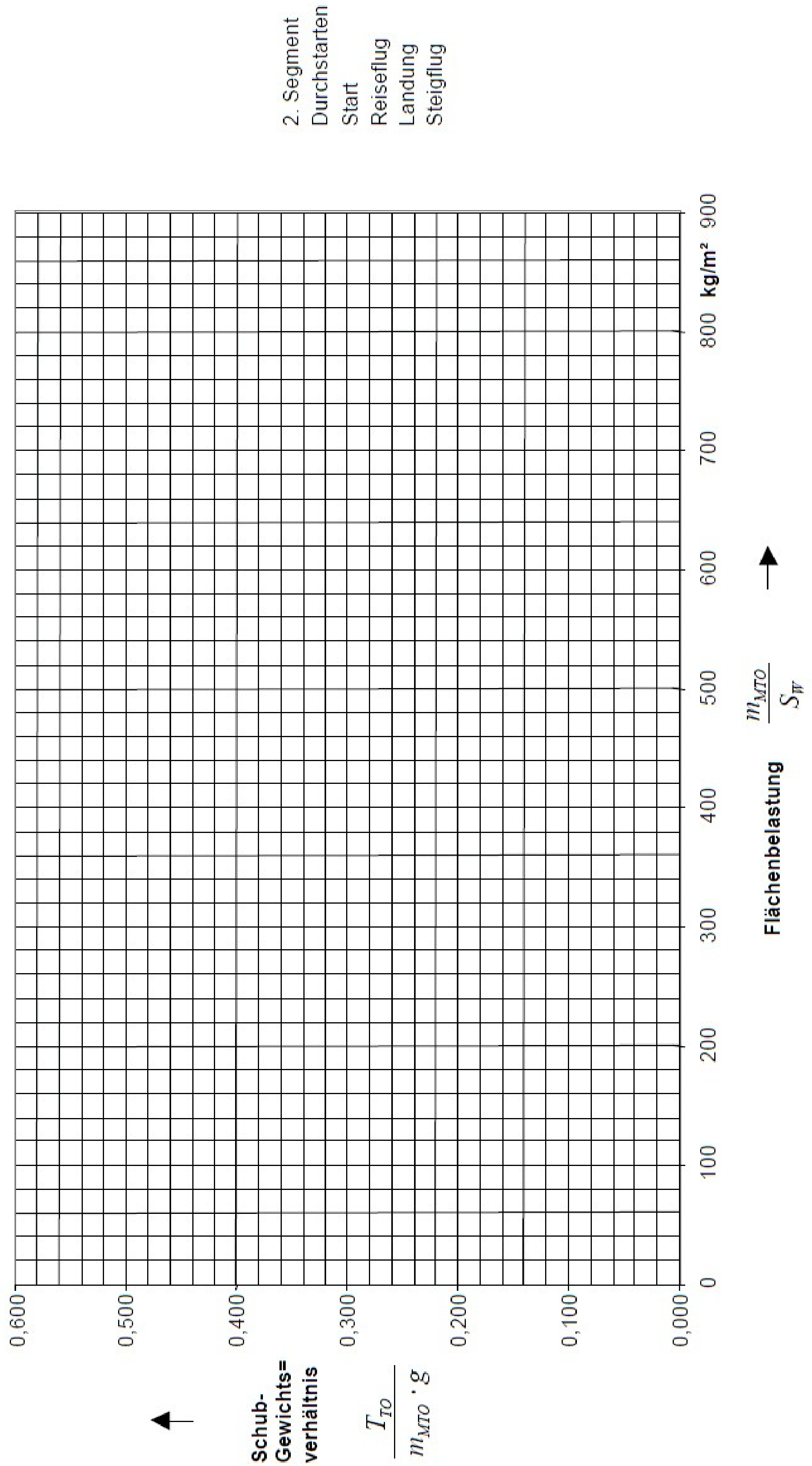
- Specific fuel consumption for cruise and loiter of the hydrogen engine:
- *Standard results from preliminary sizing (see next page " More results for task 2.2")*
- Change of parameters in % compared to the standard A320 (Task 2.1)
  - o Change of max. take-off mass:
  - o Change of max. landing mass:
  - o Change of operating empty mass:
  - o Change of fuel mass:
  - o **Change of energy used or change of energy-equivalent kerosene fuel mass:**
  - o Change of wing area:
  - o Change of take-off thrust:

More results for task 2.2

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**!


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
Flächenbelastung
$\frac{m_{MTO}}{S_W}$
Schub-Gewichts=verhältnis
$\frac{T_{TO}}{m_{MTO} \cdot g}$

Task 2.3 (2 points)

Airbus claimes (https://perma.cc/FP8M-JYPD)

"The widest single-aisle cabin in the sky"

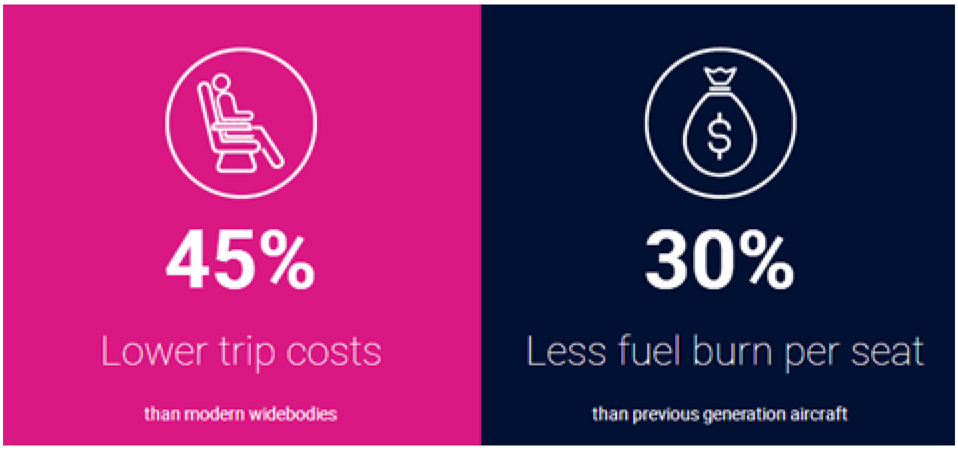
Some data:

	fuselage width	fuselage height
Boeing sing aisle (707, 727, 737, 757):	3760 mm	4010 mm
Airbus single aisle (A319, A320, A321):	3950 mm	4141 mm
Comac C919:	3960 mm	4166 mm
Irkut MC 21:	4060 mm	4060 mm

Please comment carefully!

Task 2.4 (4 points)

Airbus claimes with respect to the A321XLR (https://perma.cc/JGR6-X64C):



a) Comment on the "45%-Claim"! To what extend does it make sense?

b) Comment on the "30%-Claim"! To what extend does it make sense?

As the "previous generation aircraft" the Boeing 757 is discussed.
Calculate fuel burn from the simple approach as given below

A/C	MTOM	MZFM	range, R	passenger, Pax
B757	122500 kg	95250 kg	4445 km	279
A321XLR	101000 kg	74374 kg	6750 km	244

Fuel Consumption = (MTOM – MZFM) / (R · Pax) · 100 in kg per 100 km per passenger

(from https://doi.org/10.48441/4427.225)

Task 2.5 (3 points)

With the Airbus A321LR and A321XLR several parameters where changed:

- Fuel volume increased
- Max. take-off mass increased
- Payload reduced

Please draw a generic paylaod-range diagram and show in the diagram, how these changes individually and combined lead to more range!

Task 2.6 (5 points)

Qantas intends to fly Sydney to NewYork and Sydney to London nonstop (https://perma.cc/K4T6-E4QP).

SYD – JFK: 16000 km
SYD – LHR: 17000 km

Critics say, much fuel could be saved if a fuel stop would be used.
Consider SYD – LHR, Glide ratio: 18, SFC: 16 mg/(Ns),
Speed is calculated from a cruise Mach number 0.8 in the stratosphere.
Consider only cruise flight.
Consider a direct flight as cruise (without mission segment mass fractions) as reference (100%).

a) Assume an intermediate fuel stop in the middle of SYD – LHR.
Calculate the fuel burn relative to the reference (still no mass fractions)!
b) Assume mission segment mass fractions (only) for the intermediate stop for descent, landing, taxi, take-off, climb (from the lecture notes). Calculate the fuel burn relative to the reference!
c) Comment on your findings in a) and b).