Introduction to Aerospace Engineering

Exams

Part I – Intro Aeronautics

Note: Each set of problem sheets is bilingual. There are 7 problems on four pages (2 sheets) for each language. The first four pages contain the English version. The second four pages contain the Dutch version. You can answer using your ow preferred language: English or Dutch, independent of the group you're in.

Let op: Elke set opgaven bevat beide taalversies. Er zijn 7 opgaven op 4 pagina's (twee vellen) voor elke taal. De eerste 4 pagina's bevatten de Engelse opgaven. Daarna volgen 4 pagina's met de opgaven in de Nederlandse taal. Je kunt vrij kiezen in welke taal je het tentamen maakt: Engels of Nederlands, onafhankelijk van je groepsindeling.

Problem 1. (5 points)

In the pioneering stage of aviation the following persons were involved:

(a) George Cayley
(b) Otto Lilienthal
(c) Samuel Langley
(d) Albert Plesman.

Which sentence belongs to which person?
Answer in the form 4 combinations: [character] – [number of sentence]

1. Was one of the founders on the oldest, still existing airline
2. Lost the competition (for the first powered flight) with the Wright Brothers by a couple of weeks
3. Was the first to recognize the different systems (like for lift, thrust) in a flying machine
4. Did a lot of tests with gliders, and died before he could use engines.

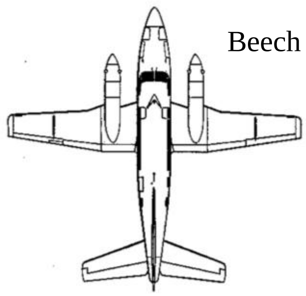
Problem 2 (10 points)

A typical structural element is a beam, which has two girders and a web plate.

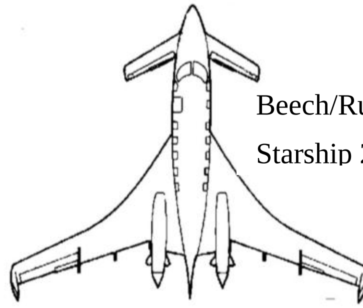
a. Mention at least two structural parts that are based on this concept.
b. Describe what loads (forces) are carried by the girders and web plate in case of tension and in case of bending.
c. The web plate is loaded by shear stress. What are the deformations and failure modes?

Problem 3. (20 points)

For the Beech 99 the position of the neutral point relative to the aerodynamic center of the wing l_{np} can be described using the distance between the aerodynamic centers of of wing and horizontal tail surface, l_H :



Beech 99

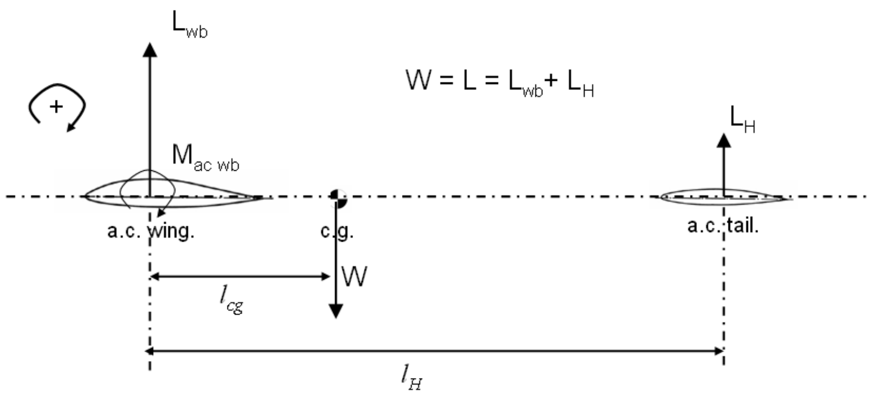


Beech/Rutan

Starship 2000

$$\frac{l_{np}}{\bar{c}} = \frac{a_t}{a} V_H \left(1 - \frac{\partial \varepsilon}{\partial \alpha}\right) \qquad \text{waarin} \quad V_H = \frac{S_H l_H}{S\,\bar{c}} \qquad a_t = \left(\frac{dC_L}{d\alpha}\right)_{tail} \qquad a = \left(\frac{dC_L}{d\alpha}\right)_{wing(+body)}$$

In which the variables S_H and S refer to the surface areas of the horizontal tail surface and the wing respectively. ε is the symbol for the downwash locally at the position of the horixontal tail surface.



a) Should the center of gravity for a conventional aircraft like the Beech 99 be located in front of the netural point or behind the neutral point for static longitudinal stability? Explain why and start with the moment equation using the diagram above.

At a canard plane like the Starship, the wing is located all the way back where for covnentional aircraft the tail is located. The horizontal tail plane is nu replaced by a canard surface at the nose. Let us call the distance between the aerodynamics centers of the main wing and the canard plane l_C and use S_C for the area of the canard surface.

b) Should the Cm_α of the Starship have a positive or negative sign for longituinal static stability? And what does this mean for the location of the center of gravity?

For the Cm_α of a canard plane we can write (the index c instead of H refers to the canard surface) and l_{cg} is now the distance bewteen the center of gravity and the aerodynamic center of the main wing:

$$C_{m_\alpha} = a_c V_H - a\frac{l_{cg}}{\bar{c}} \qquad \text{in which} \quad a_c = \left(\frac{dC_L}{d\alpha}\right)_{canard} \quad \text{and} \quad V_H = \frac{S_C l_C}{S\,\bar{c}}$$

c) If the center of gravity is located exactly at the neutral point and we increase the dimensions of the canrd surface, what is the effect on the static longitudinal stability? (Use the formulae given above to explain your answer)

d) During a stall of a canard plane, which should stall first for static stability: the canard surface or the main wing? Explain your answer.

Part II – Aerodynamics

Please start this part on a new sheet (to facilitate the distribution for correction.)

Problem 4 (15 points)

A Boeing 727-200 flies level in **standard atmospheric conditions at sea level**:

$p_0 = 1.01325 \cdot 10^5$ Pa
$\rho_0 = 1.225$ kg/m^3
T = 288.15 K
$g_0 = 9.810$ m/s^2

For air is given: $\gamma = 1.40$ and $R = 287.0$ J/kg K

The following data are available for this aircraft:

Mass of aircraft, m	: 68000 kg
Stall speed, V_{stall}	: 282 km/hr
The reference wing area, S	: 149 m^2
The aspect ratio, A	: 8.125
The Oswald factor (“span efficiency factor”), e	: 0.800
The zero-lift drag coefficient, C_{D_0}	: 0.0182

For the drag coefficient use: $C_D = C_{D_0} + \dfrac{C_L^2}{\pi A e}$

a) Calculate the drag force in [N] for this aircraft at the stall speed, V_{stall} ,
b) Same question for a Mach number of 0.300

Problem 5 (15 points)

Describe the following items briefly in a clear way:

a) Critical Mach number
b) Boundary layer transition
c) Mean camber line
d) Aerodynamic center
e) Center of pressure
f) Induced drag

Part III – Space
Please start this part on a new sheet (to facilitate the distribution for correction.)

Problem 6 (20 points)

Consider the design of a Manned Mars Lander (MML). The atmosphere of Mars is very thin with a pressure of about 1% of the atmospheric pressure at the surface of the earth.

- The exhaust jet speed of the propsulsion system of the lander is 3000 m/s
- The average gravitation acceleration on Mars $g_M = 3.73$ m/s^2
- The earth standard gravitiation acceleration is $g = 9.81$ m/s^2
- The total mass of the MML, M = 14,500 kg

For the phase A of the MML project the following data are available: The structural design of the lander allows a maximum static load < 12g . Coming from a descent of 100 meters above the Mars surface with a speed of 150.23 m/s the speed has to be reduced to a value of 1.51 m/s at an altitude of 1 meter with a constant decelleration. Altitude difference at Mars can be ignored and also the atmospheric drag.

a) What are the three main function of a spacecraft structure
b) Is the design of the Apollo Lunar Module an appropriate starting point for the phase A design of the MML? Explain your answer.
c) Calculate the descent time
d) Calculate the required thrust force T (in kN) for this lander.
e) Calculate the amount (in kg) of fuel brandstof that is used and the relative mass change in percents of the initial mass.
f) Show that the requirement <12g eis is met

Problem 7 (10 points):

a) Mention the 6 Kepler parameters that are commonly used to characterize the orbit of an arbitrary satellite. Discuss each element briefly.
b) What is the assumption that has to be made to describe the orbits in such a way?