Exercises Lecture 3
Climbing and descending flight

Dr. ir. Mark Voskuijl
Daan Westerveld

Delft University of Technology

Exercise 1

Which of the following statements is correct?

In climbing flight we can state that:

A) $L \neq W$ and $T = D$
B) $L = W$ and $T \neq D$
C) $L = W$ and $T = D$
D) $L \neq W$ and $T \neq D$

Exercise 2

An aircraft weighing 70,000 kg is climbing out after take-off. During this climb the aircraft flies with an angle of attack of $\alpha = 2°$, while the pilot observes an angle of 17° between the view from the cockpit and the horizon. Furthermore, it is known that during this climb out the aircraft has a drag of $D = 20$ kN.

What is the thrust (in kN) needed for this steady climb out?

Exercise 3

Below you see a picture of Lukla Airport located in Nepal.

Figure 1: Lukla Airport (Image courtesy of Tom2008Tom, CC - BY - NC - SA)

What would be a more important climbing property at this airport?

A) Having a large maximum rate of climb.
B) Having a large maximum climb angle.

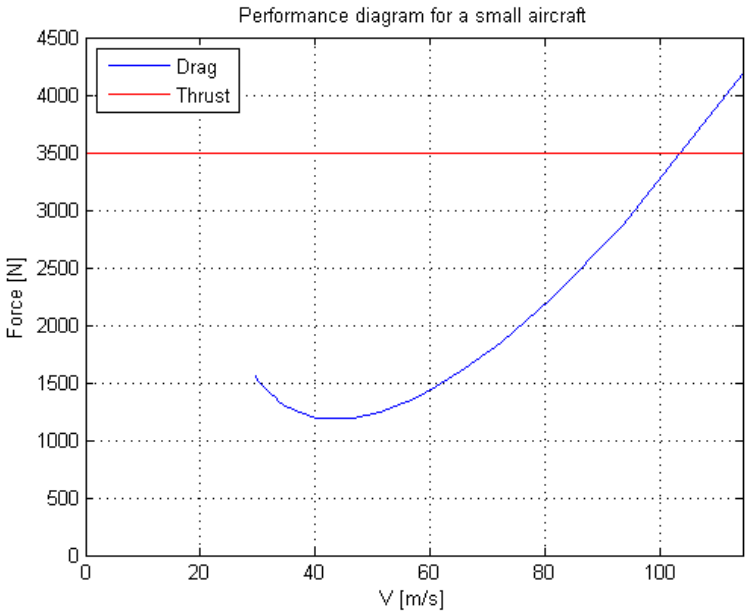
Exercise 4

The pilot cannot observe the climb angle γ. Why is this the case?

A) The angle the pilot sees outside is the angle of attack, not the climb angle.
B) It depends on the angle of attack the aircraft is flying at.
C) The angle the pilot sees outside is the pitch angle, not the climb angle.
D) The pilot can observe the climb angle.

Exercise 5

Below you see the performance diagram of a small, lightweight jet aircraft operating at a specific altitude. It is given that the aircraft weighs 2038.7 kg.



What is the maximum climb angle of this aircraft (in degrees)?

Exercise 6

The MD-11 is a three-engined jet airliner.

Figure 2: The MD-11 Image courtesy of Boushh_TFA, CC - BY - SA)

For this aircraft, the following values are known:

- $m = 273.3 \cdot 10^3$ kg
- $S = 338.9$ m^2
- $C_{D_0} = 0.0162$
- $k_1 = 0$
- $k_2 = 0.0440$

Furthermore, the aircraft is flying at sea-level conditions ($\rho = 1.225$ kg/m^3). You are asked to answer the following questions, using a 2-term drag polar. Finally, you can assume that thrust is independent of airspeed.

1) At what lift coefficient does the MD-11 need to fly in order to achieve the maximum climb angle?
2) What is the corresponding airspeed (in m/s) the aircraft should fly at?
3) If it is given that the aircraft produces 810 kN of thrust at this airspeed, what is the maximum climb angle (in degrees)?

Exercise 7

Consider two identical aircraft. One of these aircraft is filled to the brim with baggage, while the other is completely empty (except for the pilot). Both aircraft start gliding from the same point to the runway.

Which of the following statements is correct?

A) The light aircraft will travel a much longer horizontal distance, compared to the heavy aircraft.
B) Both aircraft will reach the runway at the exact same spot at the same time.
C) The heavy aircraft will overshoot the runway, while the light aircraft reaches the runway at the intended landing point.
D) Both aircraft will reach the runway at the exact same spot but the heavy aircraft arrives there earlier.

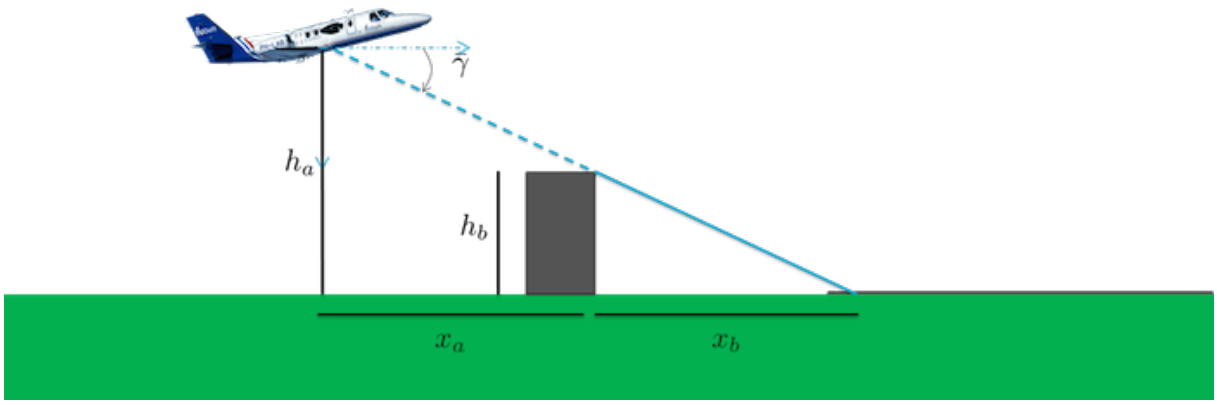
Exercise 8

A glider is flying at an altitude of 1,250 m. If the glider was to descent with its minimum glide angle, it can fly a horizontal distance of 23,850 m.

What is the minimum glide angle for this aircraft, in degrees? (Keep in mind, the glide angle is defined positive downwards!)

Exercise 9

A pilot of an aircraft with engine trouble (so no thrust) wants to land at the nearest airport. Ahead of the airport there is a building of h_b meters high, as shown in the figure.



The aircraft has the following lift-drag polar:

- $C_{D_0} = 0.02$
- $k1 = 0$
- $k_2 = 0.0352$

And the geometric data is as follows:

- $x_a = 1000$ m
- $x_b = 715$ m
- $h_a = 119.9$ m
- $h_b = 50$ m

1) What is the minimum glide angle ($\bar{\gamma}$, so a positive number) of the aircraft?
2) Is the aircraft able to make the runway?

Exercise 10

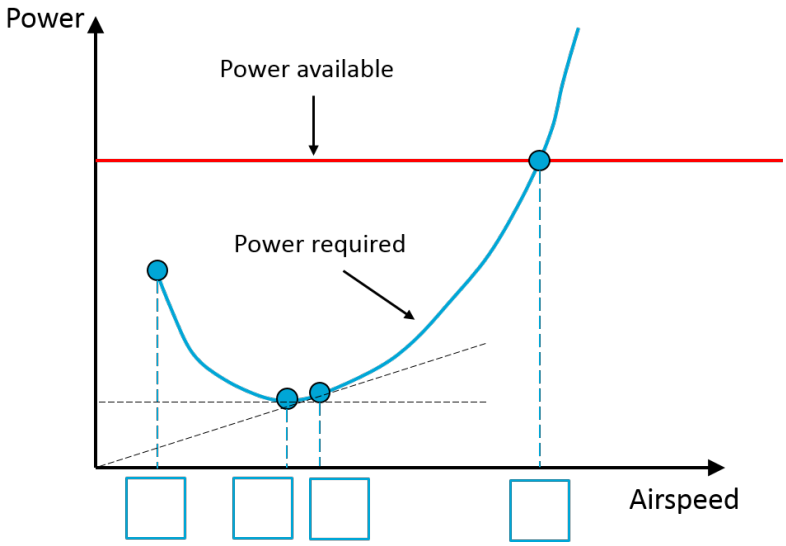
An aerobatics aircraft wants to get to a 100 meters higher as quickly as possible. The pilot of the aircraft does not care what the airspeed of the aircraft at this altitude will be, as long as it is fast enough to keep flying at this altitude.

What is the better option to get there, taking the needed airspeed into account?

A) Climbing with the maximum sustained climb rate
B) Trading most kinetic energy for potential energy, such that the aircraft stays just above the stalling speed at the higher altitude.
C) Fly a spiral manoeuvre opwards.
D) Trading all kinetic energy for potential energy.

Exercise 11

Below you see a typical performance diagram. Indicate the square box corresponding to the condition for maximum rate of climb.



Exercise 12

A Pilatus PC-9 is climbing out from a Swiss airport, having an elevation of 430 m. In order to not disturb the people living around the airport it is climbing with a maximum rate of climb to an altitude of 1500 m. On this particular day the meteorologists office measures a pressure of $p = 100$ kPa, and a temperature of $T = 5$ °C.

Figure 3: The PC-9 Image courtesy of Chaika12, CC - BY - NC - SA)

The following data for this aircraft is known:

- $C_{D_0} = 0.0144$
- $k_1 = -0.0029$
- $k_2 = 0.0729$
- $P_a = 466.3$ kW
- $S = 16.29$ m^2
- $m = 2350$ kg

1) At what airspeed (in km/h) is the aircraft flying?
2) At what rate (in ft/min) is the aircraft climbing?
3) If we neglect that the aircraft becomes lighter due to fuel usage and we neglect the change of density during this climb, what is the time it takes for the aircraft to reach the altitude of 1500 m (in minutes)?

Exercise 13

Does the minimum rate of descent change with altitude?

A) Yes, because the density is higher at lower altitudes the minimum rate of descent will be smaller.
B) Yes, because the pressure is higher at lower altitudes the minimum rate of descent will be smaller.
C) No, altitude does not have an effect on minimum rate of descent.
D) Yes, because the density is higher at lower altitudes the minimum rate of descent will be higher.

Exercise 14

Consider an aircraft that is flying, with its engines turned off for training purposes, at an altitude of 500 meters ($\rho = 1.1673$ kg/m^3). The following properties of this aircraft are known:

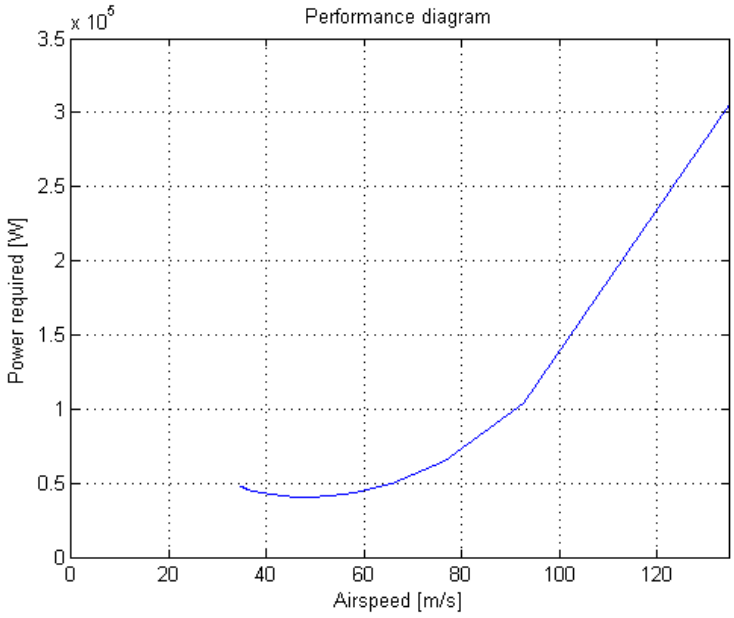
- $S = 26.1$ m^2
- $W = 53,955$ N
- $C_{D_0} = 0.0298$
- $k_1 = -0.0081$
- $k_2 = 0.0397$

1) What is the minimum rate of descent for this aircraft (in m/s)? (*Keep in mind that a downward descent rate is positive*)

2) How long can the aircraft stay in the air (in min), neglecting the change in air density?

Exercise 15

The performance diagram shown below belongs to a propeller aircraft with a weight of 1500 kg and a wing surface area of 16.23 m^2. Moreover, it is flying at an altitude where the air density equals 1.1111 kg/m^3.



What is the minimum rate of descent in gliding flight (in m/s) for this aircraft? *Keep in mind that a downward descent rate is positive.*

Exercise 16

Consider a 2-engined propeller aircraft climbing out (steady, straight flight) from an airport located at sea-level elevation. For this aircraft the following lift-drag polar is known:

$$C_D = 0.0178 - 0.0024C_L + 0.0454C_L^2$$

Moreover, some other properties of this aircraft are known:

- $W = 100.45$ kN

- $S = 95$ m^2
- $P_{a_{max}} = 1600$ kW (this is the total power)

1) Calculate the maximum rate of climb (in ft/min) for this aircraft.
2) Due to unknown circumstances, one of the engines fails during the climb-out. What is the rate of climb with one engine failed (in ft/min)? Assume that the aircraft flies at the airspeed for optimal rate of climb with both engines working.
3) The owner of the aircraft wants to be able to always have a rate of climb of at least 1575 ft/min during climb-out. What should be the total power installed (in kW) in the aircraft in order to meet this requirement?

Exercise 17

Below you see a performance diagram. Please name the boxes correctly.