EG-194 Introduction to Aerospace Engineering
Assignment 2, 2018

The first four sections questions on this sheet should each take around 1 hour to complete. They are based on examination questions. In an examination, you would have to answer them in less than half that time to get full marks. You should limit yourself to spending no more than 6 hours on the last question. It is an open question. You could spend a lot longer improving your answer.

The aim is that you should do these questions shortly after I have gone through the relevant lecture material. They should be useful to your learning of the topics. The submission deadlines are as follows for the first four sections

- Question 1 to 3, Friday 2nd November at 5 pm
- Question 4 to 6, Friday 9th November at 5 pm
- Question 7 to 9, Friday 16th November at 5 pm
- Questions 10 to 12, Friday 30th November at 5 pm

For these submissions all that will be required on the above days is the value of the answer. The link to the submission will appear within the Assignments area of the EG-194 Blackboard site. Your marks will appear immediately after the above submission deadlines.

The deadline for submission of the solutions to **all** questions, at this time I need to see how you got your answer, including the question in the ‘Additional Question’ section is 12:50 on Thursday 7th December 2018. If you got your answer wrong as part of the submission of the answers then you are allowed to try again and get the correct answer as part of this submission. There are two options for submitting the assignment. A Blackboard assignment has been created to which you can make your submission. Alternatively, I will be available in GH043 during the timetabled lecture to receive hard copy submissions. In this case, submissions have to be handed to me as both you and I have to sign to record their submission. Do not forget to include the coursework cover sheet, I will not accept your submission without one.

Ensure your student ID is on every piece of paper you submit.

Solutions to the assignment will be posted on Blackboard shortly after the submission deadline

Please insert any standard constants here.

$\rho_0 = 1.225$ kg/m^3
$\mu_0 = 1.8\times10^{-5}$ N m^{-2} s
$\sigma = \dfrac{20-H}{20+H}$ where H is the altitude in km

All the equations and variables required for this assignment are contained on the Data Sheet

Questions related to aerodynamic forces

A 1/20th scale model of an aircraft was tested in a wind tunnel located in La Paz, Bolivia, which is at an altitude of 3.5 km above sea level. The wind tunnel was open to the local atmospheric conditions and the air speed used in the tests was 16 m/s. The following equations are true for the full-scale aircraft and you should assume they are true for the model.

$$C_L = 0.1(\alpha + 2) \qquad\qquad C_D = 0.03 + 0.04\, C_L^2$$

$$C_{Mac} = -0.16$$

In the above equations the angle of attack is measured in degrees. The full-scale aircraft has a mean chord of 4 m, a wing area of 128 m^2 and weighs 300 kN. The aerodynamic centre is located at a distance of $0.1c$ from the leading edge.

Question 1.
What lift would be measured in the wind tunnel test when the angle of attack is 2°?

Question 2.
What value of the pitching moment about the aerodynamic centre would be measured in the wind tunnel test at an angle of attack of 2°?

Question 3.
What angle of attack would lead to a pitching moment about the leading edge of -1.8 N m in the wind tunnel tests?

Questions related to cruise flight

An aircraft weighs 60 kN and has a wing surface area of 40 m^2. The aircraft has a C_{LMAX} of 1.6 and its drag equation is given by

$$C_D = 0.025 + 0.03\, C_L^2$$

The aircraft uses turbojet engines that produce a maximum total thrust of 20 kN at sea level. Assume that maximum available thrust is proportional to density.

Question 4.
The aircraft glides with the aerodynamic characteristics associated with minimum power conditions. What is the glide angle?

Question 5.
The same aircraft later climbs also with the aerodynamic characteristics associated with minimum power conditions. Assuming that the small angle approximation is valid, what is the equivalent airspeed at which the aircraft climbs?

Question 6.

What are the maximum and minimum cruise speeds of the aircraft at an altitude of 5 km?

Questions related to cruise performance

A jet-powered aircraft has a maximum still air range of 3000 km when flying at an altitude of 10 km under constant altitude cruise conditions with thrust proportional to density. The sea level value of thrust is 15 kN and the engines use 0.1 kg of fuel per N thrust per hour. The weight of the aircraft when full of fuel is 100 kN of which 30 % is fuel. The surface area of the wings of the aircraft is 50 m^2.

Question 7.

What value of f should be used in the range equations?

Question 8.

What would be the maximum still air range of the aircraft if it flew under the same aerodynamic conditions at an altitude of 5 km?

Question 9.

What are the values of C_{D0} and K for the aircraft based on the information related cruise at 10 km?

Assume the aircraft starts cruise using all available thrust and show this leads a value of 0.05 for $C_D \ / \ C_L$. Show that the range equation leads to $\sqrt{(C_L\ )}\ /\ C_D$= 25.28. The rest I will leave to you.

Questions related to manoeuvring flight

An aircraft weighs 12 kN, has a wing surface area of 10 m^2 and its drag equation is given by

$$C_D = 0.012 + 0.03\ C_L^2$$

Its propeller engine can produce 254 kW of power at sea level and power is proportional to density. The aircraft has a maximum coefficient of lift of 2.2 and a maximum load factor of 6.

Question 10.

The aircraft performs a horizontal banked turn with radius 150 m at a bank angle of 70°. What is the speed of this turn?

Question 11.

How much power is required to perform a horizontal banked turn with radius 150 m at a speed of 60 m/s at sea level?

Question 12.

At an altitude of 5 km, the aircraft attempts to perform a 160 m radius horizontal banked turn at a speed of 90 m/s. Show that strength and stall do not limit this turn. Also show that the aircraft does not have enough power to perform the turn.

Additional question

As part of the design project in semester 2 students are asked to design a glider. The glider consists of a fuselage, front wings, tail unit (this is only the horizontal part, the vertical part is included in the fuselage), jet engine (to allow it to take off and climb) and must carry an egg passenger. For this question the following table gives details of the weights associated with the components and any size limits

	Weight	Limits
Fuselage	1 N per m length	Max length 1 m
Front wings	4 N per m^2 area	Max span 1 m
Tail unit	4 N per m^2 area	Max span 0.5 m
Jet	0.50 N	Must be at least 2 cm above or below the fuselage centre line
Egg	0.30 N	No size

The aerofoil sections used for the tail and front wings are differently scaled versions of the same design. The wing was tested in a wind tunnel and the following data was obtained.

α (degrees)	-2	0	2	4
C_L	0	0.2	0.4	0.6
C_D	0.01	0.0118	0.0172	0.0262
C_M	-0.1	-0.14	-0.18	-0.22

In the table the coefficient of moment is measured about the leading edge of the wing. For the complete glider, assume that the fuselage, egg and jet do not create any lift. These extra components do affect drag by adding an additional 0.015 to the coefficient of profile drag. Additionally the tests shows that the wing stalls at a coefficient of lift of 1.6.

The wing and tail unit could be attached to the fuselage at any angle. The tail can be attached at different angle to that used for the wing. In this exercise I will limit you to a 2° angle for the tail attachment but you are free to set the wing attachment angle. Note that the attachment of the tail means that when the aircraft is flying at an angle of attack of α the tail will see an angle of attack of $\alpha + 2$.

Assume that for full glider the wing area is the sum of the areas of the front wing and tail unit. Assume the wings have no sweep angle. Other information:

- The jet produces 10 N of thrust along the direction of motion for 1.5 seconds.
- The front landing gear may be longer than the rear landing gear. This can be used to provide a non-zero angle of attack when the glider is on the runway during take-off.
- The mat used as a runway on the beach is around 2 m long.

You have to choose the angle at which you attach the wing so that the glider performs well at take-off. You may have to iterate to find suitable values of these angles. I would recommend you use Excel so that it is easy to test different values. In your submission, I want to see the following:

a) Input the data for your design in the following table. Greyed out cells and those with data already in them do not require inputs. The x distance is the distance of the centre of the component from the nose of the fuselage along the centre line of the fuselage. The y distance is the distance of the centre of the component above, positive, or below, negative, the fuselage centre line.

	x distance	y distance	Length/Chord	Span	Mass
Fuselage	0 m	0 m			
Front Wing					
Tail					
Jet					0.5 N
Egg					0.3 N

b) What are the angles at which you have attached the wing to the fuselage and the angle caused by the difference in the lengths of the landing gear?

c) How long will the jet burn before the glider takes off? For this question use the equation of motion

$$v = u + a\,t$$

The initial speed, u, is 0 m/s. You need to calculate the take-off speed. You can assume that on the runway thrust is much bigger than either drag or friction, meaning you can calculate the acceleration based purely on thrust, as this is constant the above equation is valid. Show that the under the assumptions of constant acceleration your take-off distance is less than 2 m.

d) Show that your glider has a nose up moment at take-off. You should assume that drag and the accelerating force do not contribute to the moment. Take moments about the nose of the fuselage.

e) You do not want your glider to do a vertical roll or stall at take-off. Calculate the angle of attack that leads to a zero moment about the nose of the fuselage at take-off speed.