ME136/ME236U
Problem set 1: Introduction to aerodynamics
Solutions due at 11:30 on Wednesday, 18 September

Instructions: Provide your solutions to these problem sets by the posted date. All solutions must be individually submitted. Feel free to discuss with your classmates, but everything submitted must be individual. Be explicit in your solutions. If a solution relies on computer code, you must provide the full listing of the code that you used. You may use any programming language you like. Any code must be sufficiently well documented (comments) that it can be easily understood.
Late submissions: you will lose 20% points if your submission is late by less than eight hours. For each additional hour, you lose an additional 10% points.
Last update: 2019-09-09 at 17:01:10

Problem 1

(10 points) Consider a typical light aircraft, with mass 900kg. The aircraft has a 16m^2 wing, with maximum lift coefficient $C_{L,\max} = 1.6$. What is the minimum speed $v_{\min}$ that the aircraft can fly at without losing altitude (this is also the "stall speed" of the aircraft)?
Use $\rho = 1.225\text{kg/m}^3$.

Problem 2

(10 points) In this problem, we will calculate the flow regime for various aircraft. Use atmospheric data as provided by `https://www.engineeringtoolbox.com/standard-atmosphere-d_604.html`. We will look at the following aircraft, operating in steady state at the given conditions:

1. The *Airbus A380*, with wing planform information as given in `https://en.wikipedia.org/wiki/Airbus_A380`, operating at 11km above sea level at a speed of 903km/h, with mass 500,000kg.
2. The *DG Flugzeugbau DG-808C* glider plane, with data available at `https://en.wikipedia.org/wiki/DG_Flugzeugbau_DG-800`, with operating altitude at 5km above sea level at speed 150km/h with mass 600kg.
3. The *Lockheed Martin F-22* fighter jet, with data available at `https://en.wikipedia.org/wiki/Lockheed_Martin_F-22_Raptor`, operating at 11km above sea level at speed 1900km/h with mass 29,410kg.
4. The *Sensefly eBee* mapping UAV, with data available at `https://www.sensefly.com/drone/ebee-mapping-drone/` (you'll have to estimate some data from the photographs), operating at sea level at 60km/h, with mass 0.7kg

Create a table, with one column for each of the aircraft, with the following rows (all values at the given operating condition):

1. Reynolds number
2. Mach number
3. Wing aspect ratio
4. Lift coefficient
5. Induced drag force (estimated using the formula provided in class)

Problem 3

(10 points) You are designing a quadcopter, and want to estimate the power required. The vehicle weighs 0.5kg, and has *four* propellers with thrust/torque characteristics as follows:

$$f_T = C_T \Omega^2$$
$$\tau = \gamma f_T$$

with Ω the individual propeller speed, f_T (γ) the force (torque) per propeller, and

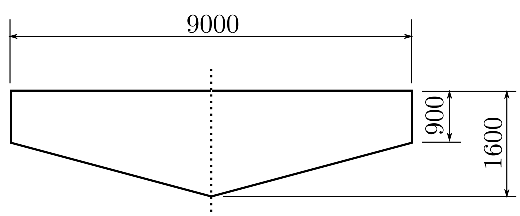
$$C_T = 6.41 \times 10^{-6} \mathrm{N}/(\mathrm{rad/s})^2$$
$$\gamma = 0.017\mathrm{m}.$$

a) Compute the propeller speeds at hover (assume each propeller carries an equal weight).

b) Compute the total mechanical power required at hover.

Problem 4

(10 points) Consider the following wing design, with all dimensions in [mm]:



The wing is made from a flat plate, with lift coefficient dependent on angle of attack α as $C_l = 2\pi\alpha$. The wing is attached to an aircraft with total mass 1000kg. You may neglect any aerodynamic effects of the aircraft body, tail, etc.

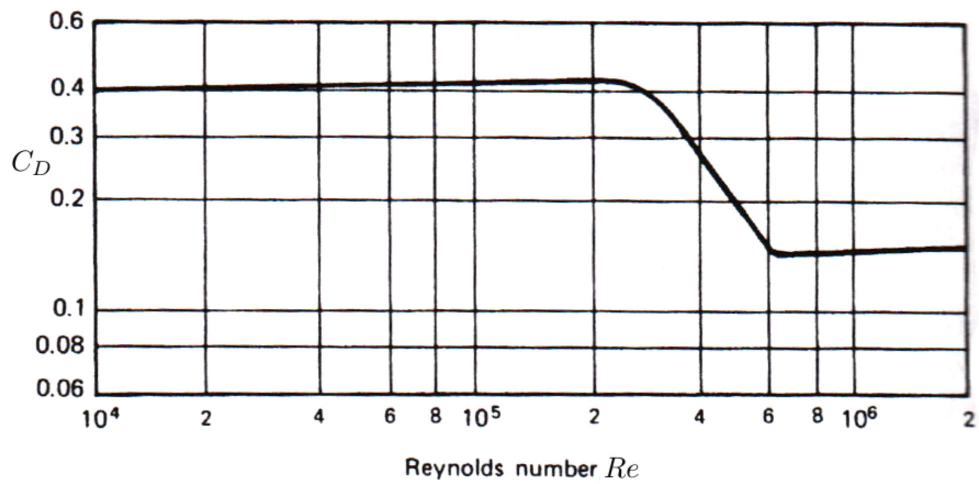
a) Compute the wing's aspect ratio (AR).

b) Estimate the wing's lift coefficient C_L as a function of the wing's angle of attack. (Note: the reference area for the wing coefficients is the wing surface area when seen from the top).

c) At a cruise speed of $55\mathrm{m\,s^{-1}}$, estimate the required angle of attack for level flight.

Problem 5

(12 points) Estimate the velocity with which a bowling ball dropped from a great height will hit the ground (that is, it's terminal velocity). You may model the bowling ball as a smooth sphere, of diameter 0.217m and with mass 7.0kg. The drag coefficient of can be read off from the following figure (where the diameter is used as the Reynolds number reference length, and the reference area is the sphere's projected surface area in the direction of the velocity, with the figure taken from B. W. McCormick, *Aerodynamics Aeronautics and Flight Mechanics.* John Wiley & Sons, Inc, 1995, Figure 4.6):



Model the atmosphere as having constant density (ρ) and viscosity (μ), with specifically $\rho = 1.225\text{kg/m}^3$ and $\mu = 18.27 \times 10^{-6}\text{Pa s}$.