Module 3A1: Fluid Mechanics I

VEHICLE AERODYNAMICS

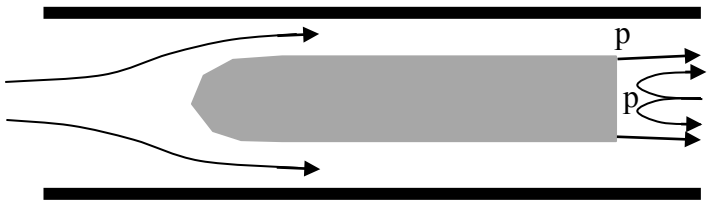
Examples paper

These lectures are at the end of the course and it may be difficult to address this examples paper in supervisions (because of backlog). Also, much of this part of the course is descriptive rather than numerical. Therefore, these questions are designed for self-study and many of the answers are in the hand-out.

Drag on bodies

1. Estimate the power needed to overcome air resistance on a typical modern passenger car travelling at 70 mph. Approximately what proportion of this is due to skin friction? How does the power consumption vary with speed?

2. Consider the flow over a cylindrical body, with diameter d , placed centrally in a pipe of diameter D, as illustrated below. The body has a streamlined nose but the rear is cut off square. The pressure p over the rear of the body is equal to that in the mainstream flow at the point of separation where there is no streamline curvature. Use a control volume momentum analysis to obtain an expression for the drag coefficient of the body in terms of d/D . Neglect boundary layer growth or skin friction drag and assume incompressible flow. What does the result suggest about the forebody drag of a round-nosed body in an unbounded flowfield?



Answer: $$C_d = \frac{\left(\frac{d}{D}\right)^4}{\left(1-\left(\frac{d}{D}\right)^2\right)^2}$$

3. Based upon your understanding of inviscid flow and boundary layers in adverse and favourable pressure gradients, explain the direction (left or right) for which airflow past the slender airfoil shape will have lower total (friction + pressure) drag.

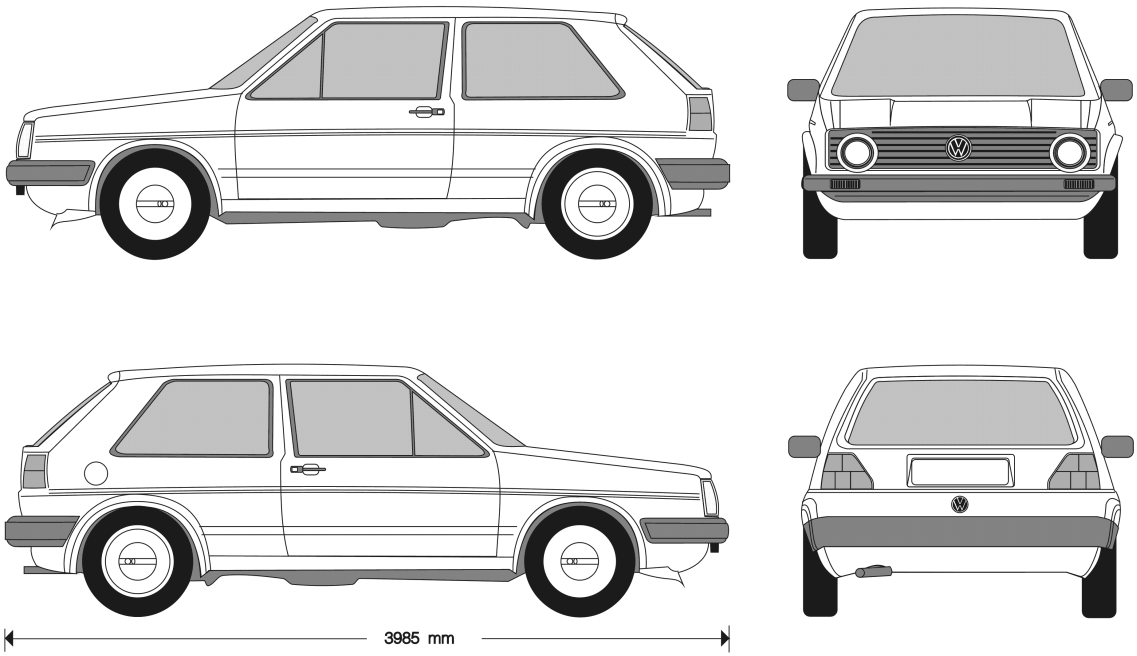
4. Plot the drag behaviour you would expect for an ellipse as a function of Length to Thickness ratio (from 1 to ∞). State which reference area you are using.

Vehicle aerodynamics

5. By examining the cars parked in the department's car park (or elsewhere) find examples of the following:
   - Boat-tailing (sides and top/bottom)
   - Fastback with attached flow
   - Small separation strip/spoiler on hatchback
   - Large spoiler for downforce (or for showing off)
   - Front spoiler
   - Flow deflector ahead of front wheels
   - Aerodynamically shielded windscreen wiper
   - Rounded off A and C pillars

   In each case remind yourself of the aerodynamic function. Also, try to find a commercial vehicle (truck) and identify aerodynamic features.

6. Below is a picture of the Golf Mk2:

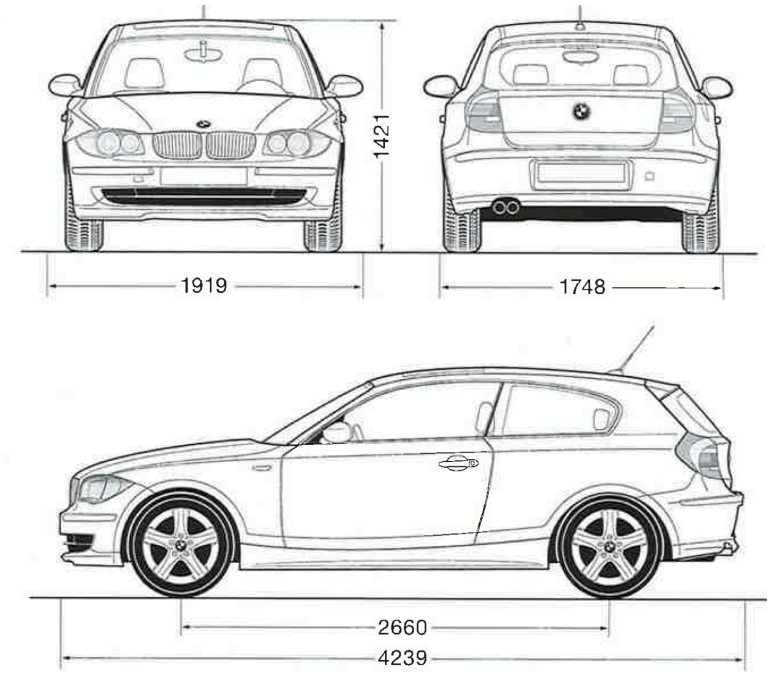


a) Indicate at least two aerodynamic/drag-saving features/devices on this vehicle.

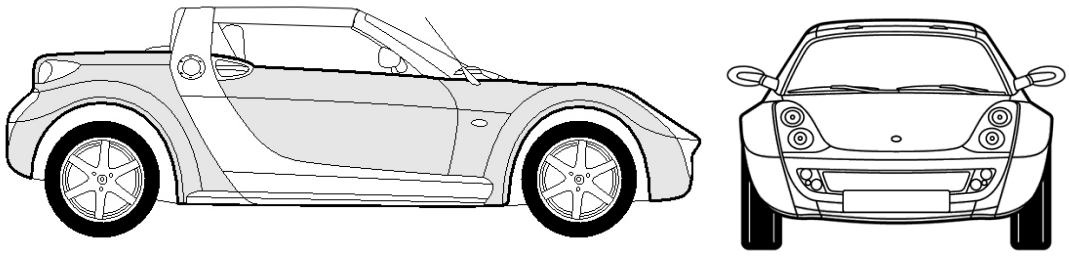
b) How could this car be improved? Find a more modern Golf in the car park and see if you are right.

7. The Babinsky household had an argument over who has the more aerodynamic car. Below are drawings and main dimensions of the BMW 1-series and the Smart Roadster. The reported drag coefficients are 0.29 (BMW) and 0.41 (Smart, with roof on).
   a) Which car incurs less aerodynamic drag (estimate)?
   b) Explain briefly why the Smart's c_d is so much worse than the BMW's.
   c) How could the Smart be improved?
   d) Despite being a hatchback, the BMW has an excellent drag coefficient, approaching the best fastback shapes. Identify a few reasons for this (compare with Golf from qu. 6)

BMW 1-series:



Smart Roadster:
For dimensions refer to table.



Smart Roadster: Dimensions	
Wheelbase (mm)	2,360
Track width front (mm)	1,357
Track width rear (mm)	1,392
Length (mm)	3,427
Width (mm)	1,615
Height (mm)	1,207

8. If a car has a lift coefficient of 0.5 (based on frontal area) and a mass of 1 ton, at what speed do we need to worry about lift? (estimate your answer)