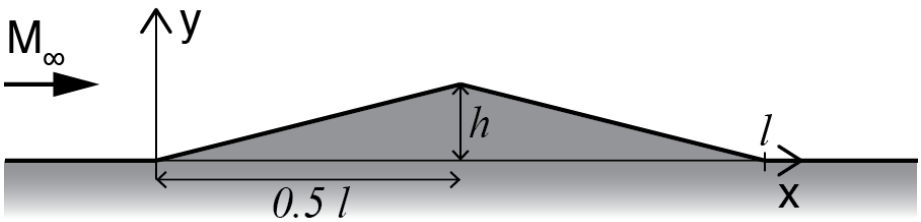
Delft University of Technology **DEPARTMENT OF AEROSPACE ENGINEERING**		
Course: Aerodynamics 2;	Code: AE2130-III	Course year: 2
Date: Wednesday 9 April 2014		Time: 14:00 – 17:00
On the top of <u>each</u> answer sheet write: initials, name, student number, sheet number/total number of sheets **This exam consists of 5 questions.**		

Problem 1 [25 points]

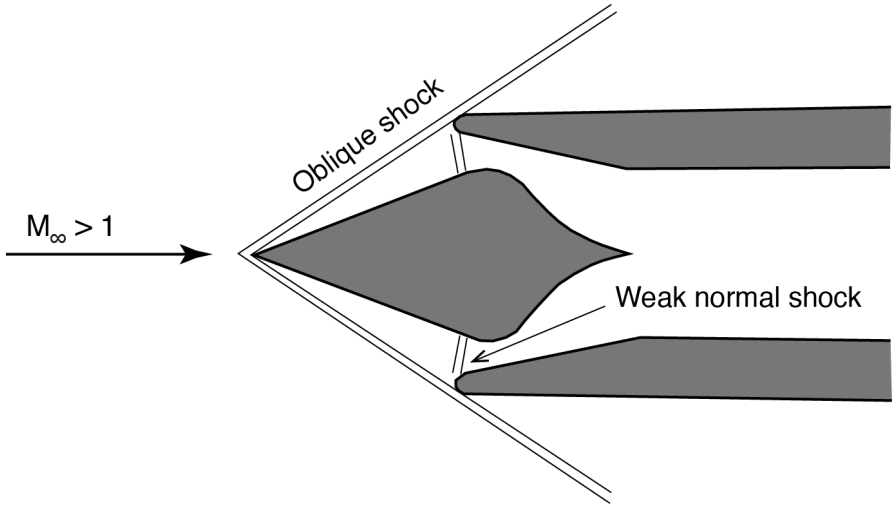
Air flows over a wall with a small triangular bump at $M_\infty = 2.6$. The height to length ratio of the bump is $h/l = 0.05$ and the length is $l = 0.2$ m. The free-stream static pressure and density are 0.2×10^5 Pa and 0.8 kg/m^3 respectively.



i. Draw the flow field over the bump, include (if present): streamlines, shock waves, expansion waves and slip-lines.
ii. Compute the drag force caused by the bump using shock expansion theory.
iii. Repeat question ii) using linear theory, compare the values and comment on the difference.

Problem 2 [20 points]

Consider an oblique shock inlet (also called spike inlet) as it is shown below:



i. Explain the purpose for which oblique shock inlets are used on supersonic aircraft.
ii. Assume a free stream Mach number of $M_\infty = 1.6$. What is the smallest deflection angle imposed by the spike inlet such that the flow is already subsonic downstream of the oblique shock, justify your answer.

Problem 3 [25 points]

Consider a supersonic wind tunnel that is designed to have *Mach 3* in the test section. The test section has an area cross-section of *625* cm^2. Upstream, the tunnel is connected to a pressurized reservoir where air is stored at a temperature of *300 K*. Downstream of the test section the air exits directly into the ambient (p_{amb} = *100 kPa*).

i. Determine the minimum total pressure at which the wind tunnel can be operated and the corresponding mass flow.
ii. In order to make the operation of the tunnel more efficient, a diffusor is added to the exit. What shoud be the minimum area of the diffusor such that the tunnel can still be started.
iii. The diffusor is removed and a pitot tube is installed in the test section. The pressure in the reservoir is decreased to *200 kPa*. What is the pressure that is measured by the pitot tube?

Problem 4 [10 points]

Starting from the 2nd law of thermodynamics, demonstrate that the airflow across a normal shock wave experiences a decrease in total pressure.

Problem 5 [20 points]

Consider an aircraft flying at M_∞ = *0.7* at an altitude of *h = 10 km*, at this height the pressure is *26 kPa* and the temperature is *223 K*. The wing of the aircraft has a critical Mach number of 0.8.

i. What is the pressure on the airfoil at the minimum pressure point?
ii. What is the velocity of the flow at this location?

Values of gas properties

Universal gas constant: R_0 = 8314 J/Kmol K; Air gas constant: R_{air} = 287 J/Kg K;
Specific heat of air: c_p = 1004 J/Kg K