ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2018 SESSION

Open-book examination
Calculators : only authorized models
Duration : 3 hours

16-MC-B3 Advanced Fluid Mechanics

IMPORTANT REMARK: For all the questions, we strongly recommend that you start by making a graphical sketch of the problem, identifying all the relevant variables. For each solution, make sure to state all the assumed hypotheses and all the simplifications made. Detail as much as possible all the different steps of your solution.

NOTE: The gravitational acceleration can be taken as $g = 9.81$ m/s^2.

Question 1 (20 points)

A heating system is used to transport and deliver hot air (at 45°C) at atmospheric pressure. The system is made first of a circular metallic pipe of 250 mm in diameter in which the air flows at an average velocity of 2 m/s. After a transition section, the air then passes through a rectangular metallic duct with a height of 150 mm (due to space restrictions) and a width of b.

Assuming that all metallic surfaces are smooth ($\varepsilon = 0$), we ask to determine the with b so that the head loss per unit length is the same in both the circular pipe and the rectangular duct.

Question 2 (20 points)

A well hit, smooth, table tennis ball leaves the paddle at a velocity $U = 18$ m/s. If the ball has a diameter $D = 38$ mm and a mass $M = 2.5$ g, we then ask to evaluate the initial deceleration of the ball, just as it leaves the paddle ; give your answer in multiples of the gravitational acceleration g. You may also assume that the air is at standard pressure and temperature.

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Question 3 (20 points)

The pressure drop Δp in a smooth pipe depends on the diameter D and the length L of the pipe. It also depends on the average flow velocity U, and on the viscosity μ and the density ρ of the fluid.

Using dimensional analysis, we ask to determine all the non-dimensional numbers that define this problem as well as the general functional relationship that links them.

Question 4 (20 points)

Upstream of the throat of an isentropic converging-diverging nozzle the flow properties are: U = 150 m/s, p = 100 kPa (abs.), and T = 20°C. Knowing that at the exit of the nozzle the flow is under-expanded at a Mach number of Ma = 2.5, we ask to determine the mass flow rate of air if the throat area is $A = 0.10\ m^2$.

Question 5 (20 points)

A closed water tank, at atmospheric pressure, is perforated. The water exiting the tank has an estimated velocity of U = 5.5 m/s. We ask to determine the height of the water level above the hole.