ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2017 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)

Water is pumped to an elevated tank on the roof of an industrial building. The pump is connected to that tank by a 10 cm diameter vertical new steel pipe. At the exit of the pump, we measure a flow rate of 20 liters/s, a gage pressure of 1600 kPa and a water temperature of 20 ºC.

Based on this, what would be the expected pressure in the pipe 80 m above the pump's exit?

Question 2 (20 points)

An aircraft has a maximum lift coefficient of 1.4 (immediately prior to stall) and a normal landing lift coefficient of 1.2. Knowing that the landing velocity is 4 m/s higher than the stall velocity, we ask to determine both the landing and stall velocities of this aircraft.

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Question 3 (20 points)

The Magnus effect produces a side (lift) force on a moving spinning ball.

Assuming that this aerodynamic force F is a function of the diameter of the ball D, the free-stream velocity U, the air density ρ, its viscosity μ, the roughness height k_s, and the angular spin velocity ω; we ask to determine all the relevant dimensionless parameters that characterize this flow problem, as well as the general functional form that relates them.

Note: we suggest using ρ, U, and D as repeated variables.

Question 4 (20 points)

A rocket propulsion system is designed to operate at sea level with an ambient atmospheric pressure of 100 kPa. The total pressure and temperature of the propulsion gas are respectively 2.0 MPa and 3300 K; the gas constant is 400 J/(kg·K) and the ratio of specific heats is 1.2.

4.1) We ask to determine what would be the area ratio of the nozzle to produce an ideally expanded jet (i.e. an isentropic flow condition).

4.2) We then ask to determine the total propulsion thrust in these conditions if the throat area is 10 cm^2.

Question 5 (20 points)

A pressurized water tank is filled up to a height of 5 m. A pressure gage connected to the top of the tank indicates a relative pressure of 200 kPa. A hole is then perforated at the bottom of the tank. Estimate the initial velocity of the water flowing through that hole.