Class Test 4; Fluid Mechanics Sec 2

Date: 08/11/2020

Time: 2 hours; Time of start: 3 PM

Total marks: 140

Solve the questions on your notebook or sheets. Scan them when done and then share the google drive link to the google form link that will be shared with you.

State all assumptions clearly and pointwise manner.

Solve all problems with a clear schematic and legible handwriting.

Scribbles and doodles will not attract any marks.

Code of ethics: The questions should be solved by the candidate on their own without any discussion with any other student(s) or without the help of any other resources available. This is an exam and not an assignment. If you agree to this ethics code then declare it on top of your answerscript and sign it.

This question paper contains seven questions

Q1. A glass contains 80 percent water and a large ice cube. Ice has a specific density of 0.9. As the ice melts what happens to the level of water in the glass? Prove your result mathematically. It may be assumed that no water is lost due to evaporation. (10 Marks)

Q2. An engineer is extruding wire through a die. Immediately after the extrusion process the wire is quite hot and the engineer decides to cool it with the help of a cooling liquid. For this he bores a cylinder so that the gap between the wire and cylinder is 1 mm. The length of the block is 1 m. The gap between the wire and cooling cylinder is filled with a liquid has a viscosity which has a peculiar formula $\mu = (10 + \alpha) \times 10^{-2+\beta}$ where α represents the last two digits of your roll number and β is equal to the remainder of the sum of the digits appearing after the department alphabets of the roll number, when divided by 4 (For example: if your roll number is 18ME10023 then $\alpha = 23$ and $\beta = 2$). The wire is extruded at a rate $U = \alpha$ m/s and the wire has a diameter of $(2\beta + 1)$ cm. Find out the force required by the engineer to pull the wire through the cooling block. (20 Marks)

Q3. During the supercyclone Amphan, two brave yet somewhat clumsy meterologists Brad and Edward were measuring the barometric pressure and wind velocity at two locations. Brad was at a distance 400 m from the eye of the supercylone as ascertained later from satellite imagery. His barometer shows a pressure of $(100 - \alpha)$ kPa absolute while his wind-vane anemometer measures a velocity of $(2\beta + 20)$ m/s where α represents last two digits of your roll number and β represents the last digit of your roll number. Edward has braved the storm but unfortunately has lost his wind-vane anemometer. At the moment when Brad is taking his measurements Edward is at a distance of 800 m from the eye of the storm where the pressure appears to have normalized to a value of 110 kPa as per Edward's barometer.

(a) Find out an estimate of the velocity at Edward's location.

(b) Find out whether Edward's barometer agrees with your theoretical predictions of the pressure.

Show all steps explicitly and state any assumptions. Hint: The supercyclone may be modelled as a free vortex, i.e. $v_\theta \sim 1/r$. (20 Marks)

Q4. You are at a fancy Vietnamese restaurant. You order a spicy pho (soup with veggie broth) and some quay (fried bread). You are merrily eating the quay when you notice that the bottom of the bowl has a small hole. The bowl is hemispherical in shape with a radius of $20 + \alpha$ cm while the hole at the bottom is circular with a diameter $1 + \beta/100$ mm where α is the last digit of your roll number and β represents the last two digits of your roll number.

(a) Find the time it would take for the volume of the soup to reduce to half its initial volume (10 Marks)

(b) Find the total time it would take for the bowl to empty (5 Marks)

(c) While you are contemplating the calculations of your soup drainage you may assume inviscid flow. Then it dawns on you that the soup is anything but inviscid. Discuss the approximations and their ramifications on the time required for drainage. In particular discuss what would happen if the soup were to be replaced with a mild sugarless green tea. (10 Marks)

(d) The Turks have a penchant for conical shaped cups instead of the south east Asian hemisphere bowls. Find out the time it would have taken for the pho to empty out of a conical frustrum with the top diameter equal to half the diameter of the Vietnamese bowl and bottom diameter equal to a quarter of the bowl diameter. The height of the frustrum is equal to twice the diameter of the Vietnamese bowl.

For all the calculations, you may assume that the density of pho is 1200 kg/m^3 and g = 10 m/s^2 .

(10 Marks)

Q5. Compute (a) pathlines, (b) streamlines and (c) streaklines which correspond to the Eulerian velocity field given by $(u, v) = (\frac{x}{1+t}, 1)$. You may use the initial condition $(x, y) = (X, Y)$ at $t = 0$. The pathline should be represented by eliminating the final time. For finding the streakline, you can find out the equation by eliminating t' where the particle is at (x', y') at time t' while it is found at the location (x, y) at a later time t. (10 marks)

Q6. Donald and Joe are seen sitting at the CCD lounge in IIT Kharagpur. One of them orders a bottle of plain water while the other orders San Pellegrini water (sparkling carbonated water). They start sipping on their beverages through a straw of diameter 3 mm while the glass in which the drink is poured is opaque; only the straw is visible to you. Being a sophomore at IIT, you want to impress your friends by telling them by pure observation which one has plain water and which one has San Pellegrini. Explain how you can tell which drink is which with appropriate mathematics and state any and all assumptions that you make in your work. (10 Marks)

Q7. ISRO launched 10 satellites on 07/11/2020. One of those satellites weighs a ton. The satellite is travelling at a mind-bending speed of 7.8 km/s. In order for it to make orbital shifts and tweaks, a satellite has a thruster placed such that the exiting gases are in an opposite direction to that of the direction of motion of the satellite. It can discharge up to 100 kg of gases generated from solid fuel. The velocity of discharge is 3000 m/s relative to the satellite in the opposite direction of the satellite's velocity. The fuel is to be discharged over a time period of 2 seconds.

(a) Find out the acceleration of the satellite during this time period

(b) What is the change of velocity of the satellite during this time period?

(c) What is the thrust in kN exerted on the satellite?

Assume that the problem is 1D. There are no other forces acting on the satellite. The mass lost may be neglected compared to the mass of the satellite.

(25 marks)

End of question paper