Kafrelsheikh University
Faculty of Engineering
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Subject: Fluid Mechanics
Type: Final Exam
Time allowed: Three hours
Full mark: 60
Year: 2nd year

This exam measures the ILOs a8, a13, b1, b2, b3, b15, c1, c16, c18.

Please, answer the following questions as much as you can. **Assume any missing data**

Question (1) **[Marks = 25%]**

(A) Drive the **Navier-Stokes Equations** of motion for incompressible fluid, steady and three-dimensional flows.

(B) (i) Starting from **NSE** for incompressible flow in **Cartesian coordinate**, drive for a Couette flow the following;

a) The velocity distribution in the clearance between the two parallel flat plates, if one of which is moving a velocity "U".

b) The flow rates per unit width "Q".

c) The shearing stress on the moving wall.

(ii) Oil flows between two parallel plates, one is at rest and the other moves with a constant velocity U. If the pressure is deceasing in the direction of the flow at a rate of 1.6 kg/m^2 per m. The dynamic viscosity is 0.0049 kg.s/m^2, the spacing of the plates is 5 cm and volumetric flow rate Q per unit width is 4.25 litre/s per m. What is the velocity "U"?

Question (2) **[Marks = 25%]**

(A) The period of oscillation **T** of a water surface wave is assumed to be a function of density ρ, wavelength λ, depth **h**, gravity **g**, and surface tension σ. Rewrite this relationship in dimensionless form. What results if σ is negligible? Hint: Take λ, ρ, and **g** as repeating variables.

(B) A dam spillway is to be tested by using Froude scaling with a one-thirtieth-scale model. The model flow has an average velocity of 0.6 m/s and a volume flow of 0.05 m^3/s. What will the velocity and flow of the prototype be? If the measured force on a certain part of the model is 1.5 N, what will the corresponding force on the prototype be?

Question (3) Choose the correct answer(s) **[Marks = 25%]**

A. Define and explain with sketch the following:

Buckingham Pi theorem, δ, δ_1, δ_2, Froude number, Strouhal number, Euler number, Rynolds number, Webber number, and C_d.

B. In the boundary layer over the face of a high spillway, the velocity distribution was observed to have the following form;

$$\frac{u}{U} = \left(\frac{y}{\delta}\right)^{0.22}$$

All the best

Dr./ Fadl Essa

The free stream velocity U at a certain section was observed to be 30 m/s and a boundary layer thickness of 60 mm was estimated from the velocity distribution measured at the section. The discharge passing over the spillway was 6 m^3/s per meter length of the spillway. Calculate;

a) The displacement thickness
b) The energy thickness
c) The loss of energy up to the section under consideration

Question (4) **[Marks = 25%]**

A. Find the ratio of the friction drag on the front half and rear half of the flat plate kept at zero incidence in a stream of uniform velocity. If the boundary layer is laminar over the whole plate.

B. A steady, low-speed flow of a viscous fluid between two infinitely long, parallel vertical plates, spaced a distance "h" a part as shown in the figure below. The velocity variations take place in the $x - z$ plane. The flow is completely independent of y. The flow is fully developed in the z (vertical) direction. The wall on the left ($x = 0$) is stationary, and the wall on the right ($x = h$) is moving upward at a constant speed "W_o". Assume that all pressure gradient is negligible, but that the effect of gravity cannot be neglected which acts in the negative z direction.

   a. Find expressions for "u", "v", and "w" in "x", "y", and "z" directions, respectively.
   b. What is the value of "w" at the midplane of the channel, that is $x = h/2$.