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Exam 2

CM3110 Spring

Thursday 18 February 2021

Name:

Rules:

- Closed book, closed notes.
- Two-page 8.5" by 11" study sheet allowed, double sided; you may use a calculator; you may not search the internet or receive help from anyone.
- Please text clarification questions to Dr. Morrison 906-487-9703. I will respond if I am able.
- All work submitted for the exam must be your own.
- Do not discuss the contents of the exam with anyone before 11:59pm Thursday, 18 February 2021.
- *Please copy the following Honors Pledge onto the first page of your exam submission and sign and date your agreement to it.*

Honor's Pledge:

On my honor, I agree to abide by the rules stated on the exam sheet.

Signature ________________________________

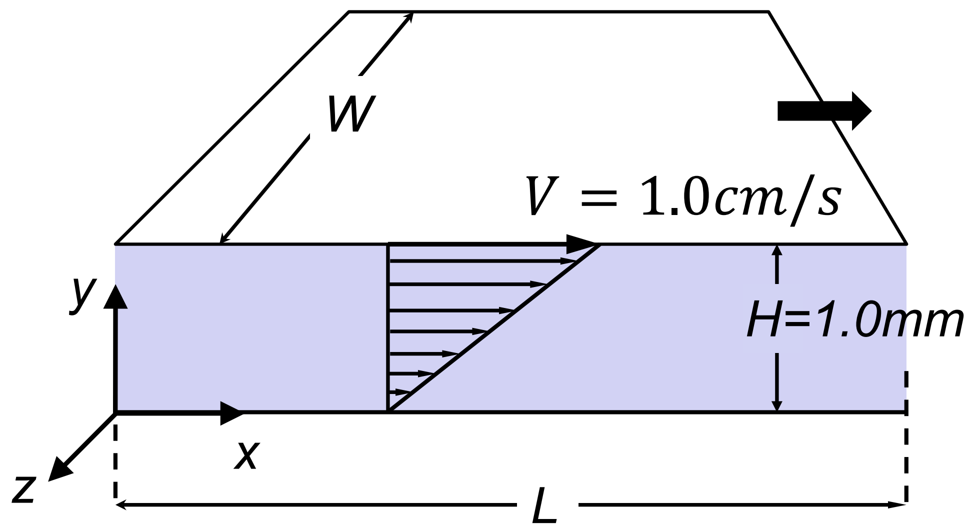
Date ______________________

Exam Instructions:

i. You may work on the exam for up to two hours and 30 minutes (150 minutes).
ii. Please submit your exam work within 150 minutes of downloading the exam.
iii. Please be neat. Only neat answers will be granted partial credit. Please use a dark pencil or pen so that your work is readable once scanned.
iv. Significant figures always count.
v. Please box your final answers.
vi. Submit your work as a single PDF file; put your name on every page. (Genius Scan is a free app that can create a PDF from photos taken by your phone)
vii. Submit your exam study sheet as a separate PDF file; put your name on the first page (at a minimum)

1. 20 points) Name two engineering quantities of interest that we could calculate from the velocity and pressure fields in a flow situation.

2. (20 points)
   a. Define fluid shear stress and explain the role of this quantity in fluid flow.
   b. How much shear stress does room temperature water produce in a simple drag flow cell (see figure; the plates are long and wide) if the speed of the top plate is 1.0 cm/s? The dimensions of the cell are given in the figure.



3. (20 points) For the flow described below, write in mathematical terms the velocity boundary conditions. Please be specific and complete in your notation (symbols).

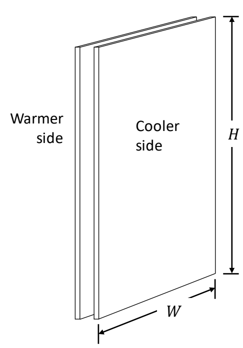
Far from the edges of the plates, fluid between two large vertical parallel plates (height H, depth W) is moving steadily in the z-direction as shown in the figure below. The flow is the result of fluid density differences driven by a temperature variation in the y-direction. The velocity profile is given by:

$$\underline{v} = \begin{pmatrix} 0 \\ 0 \\ v_z(y) \end{pmatrix}_{xyz}$$

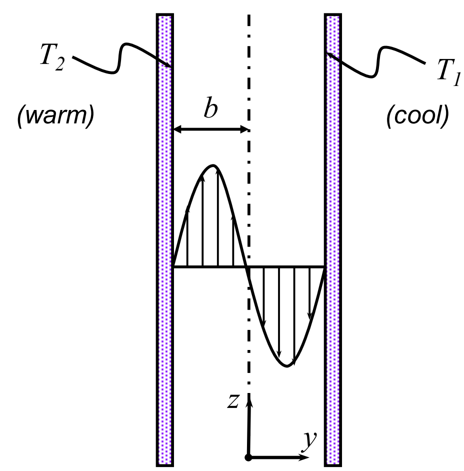
All of the following quantities are constant:

- *Fluid average density, $\bar{\rho}$*
- *Gap between the long, wide plates, $2b$*
- *Fluid viscosity, μ*

Vertical plates with fluid between:



Cross section of system:



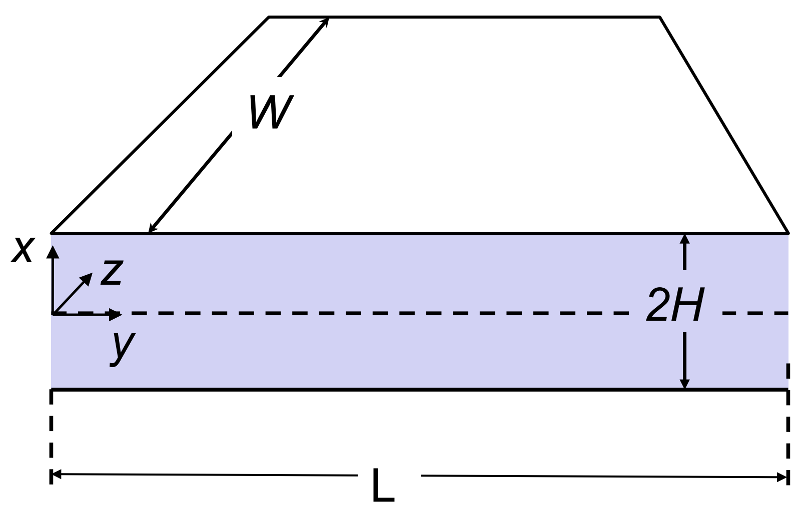
4. (20 points) A steady, pressure-driven flow is produced in a long, wide, horizontal slit. The gap between the two plates is $2H$. The upstream pressure is P_0 and the pressure a distance L downstream is a lower value P_L. A microscopic analysis results in the equations below for the steady state velocity and pressure fields (see the figure for the coordinate system; the origin of the coordinate system is halfway across the gap):

$$\underline{v} = \begin{pmatrix} 0 \\ \dfrac{H^2(P_L - P_0)}{2\mu L}\left(\dfrac{x^2}{H^2} - 1\right) \\ 0 \end{pmatrix}_{xyz}$$

$$p(y) = \frac{-(P_0 - P_L)}{L} y + P_0$$

The fluid is an incompressible Newtonian fluid of viscosity μ.

To calculate $\underline{F}$, the fluid force on the bottom wall, we need the total stress tensor $\underline{\underline{\tilde{\Pi}}}$. What is the total stress tensor $\underline{\underline{\tilde{\Pi}}}$ for this flow? Give your answer in 3×3 matrix form. Note you are not asked to calculate the force, just provide $\underline{\underline{\tilde{\Pi}}}$.



5. (20 points) Using the coordinate system shown, calculate the steady state velocity profile for an incompressible Newtonian fluid flowing slowly down a long, wide inclined plane (see accompanying figure). We are interested in the flow far from the inlet, the outlet, and the side edges of the flow. The film thickness is H, and the incline makes an angle α with the horizontal. Calculate your answer in the coordinate system shown. Indicate your assumptions. Pressure may be assumed to be uniform throughout the flow. Please be neat.