Prince of Songkla University
Faculty of Engineering

Midterm Test
7 August 2004
216-342 Mechanics of Fluids II

Semester 1/2547
9:00 – 12:00
Room R200

Name ______________________ ID ____________

Direction:

1. All types of calculators, ~~document, books~~ and dictionary are permitted.
2. There are totally 5 problems, 7 pages. Solve all of them, will you?
3. Two pages of hand-written A4 paper are allowed. No photocopy, please.

Perapong Tekasakul
Instructor

Problem No.	**Full score**	**Your mark**
1	**15**	
2	**15**	
3	**15**	
4	**20**	
5	**15**	
Total	**80**	

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ME 342 – Mechanics of Fluids II
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1. Answer all questions as good as you can. Give sufficient detail of your description. (15 points)

1.1 What is the difference between *Eulerian* and *Lagrangian viewpoints* in describing fluid motion? (3 points)

1.2 Describe the meanings of *local* and *convective accelerations*. (3 points)

1.3 What is an *irrotational* flow? How can we determine if a flow is irrotational? (3 points)

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1.4 Describe how can the Navier-Stokes equations derive from Newton's second law. (3 points)

1.5 Describe how can we calculate a flow rate between two parallel plates using differential flow analysis. (3 points)

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2. As Sittipong opens a valve, water flows through the diffuser (shown in the figure below) at an increasing flowrate so that the velocity along the centerline is given by

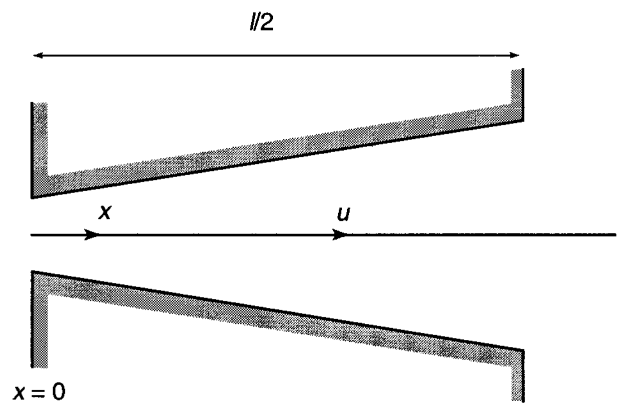
$$\mathbf{V} = u\mathbf{i} = V_0(1-e^{-ct})\left(1-\frac{x}{l}\right)\mathbf{i}$$

where V_0, c, and l are constants. Help him to solve the following problems.

(a) Determine the acceleration as a function of x and t.

(b) If V_0 = 10 ft/sec and c = 0.5 sec^{-1}, what value of l that the acceleration becomes zero for any x at t = 1 sec?

(15 points)



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3. The three components of velocity in a flow field are given by

$$u = x^2 + y^2 + z^2$$

$$v = xy + yz + z^2$$

$$w = -3xz - z^2/2 + 4$$

(a) Determine the volumetric dilation rate.

(b) Determine the rotation vector. Is this flow irrotational?

(15 points)

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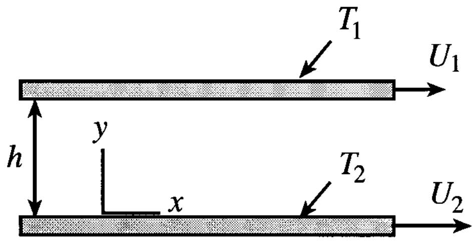
4. An incompressible, viscous fluid is placed between horizontal, infinite, parallel plates as shown in the figure below. The two plates move in the same direction with different velocities, U_1 and U_2. No pressure gradient in the x direction exists. Determine the velocity distribution between the plates. Assume laminar flow. If the temperature of the plates are T_1 and T_2, determine the temperature distribution between the plates as well. List all assumptions needed. (20 points)



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5. For each of the following stream functions, with units of m^2/sec, determine the magnitude and the angle the velocity vector makes with the x-axis at $x = 1$ m, $y = 2$ m. Locate any stagnation points in the flow field.

(a) $\psi = xy$

(b) $\psi = -2x^2 + y$

(15 points)

Life Savior

Continuity Equation

Cartesian coordinates

$$\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x}(\rho u)+\frac{\partial}{\partial y}(\rho v)+\frac{\partial}{\partial z}(\rho w)=0$$

Cylindrical coordinates

$$\frac{\partial \rho}{\partial t}+\frac{1}{r}\frac{\partial}{\partial r}(\rho r V_r)+\frac{1}{r}\frac{\partial}{\partial \theta}(\rho V_\theta)+\frac{\partial}{\partial z}(\rho V_z)=0$$

$$\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x}(\rho u)+\frac{\partial}{\partial y}(\rho v)+\frac{\partial}{\partial z}(\rho w)=0$$

Navier-Stokes Equations

Cartesian coordinates

x-component: $$\rho g_x-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)=\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)$$

y-component: $$\rho g_y-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)=\rho\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}\right)$$

z-component: $$\rho g_z-\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)=\rho\left(\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right)$$

Cylindrical coordinates

r-component:
$$\rho g_r-\frac{\partial p}{\partial r}+\mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial V_r}{\partial r}\right)-\frac{V_r}{r^2}+\frac{1}{r^2}\frac{\partial^2 V_r}{\partial \theta^2}-\frac{2}{r^2}\frac{\partial V_\theta}{\partial \theta}+\frac{\partial^2 V_r}{\partial z^2}\right]$$
$$=\rho\left(\frac{\partial V_r}{\partial t}+V_r\frac{\partial V_r}{\partial r}+\frac{V_\theta}{r}\frac{\partial V_r}{\partial \theta}-\frac{V_\theta^2}{r}+V_z\frac{\partial V_r}{\partial z}\right)$$

θ-component:
$$\rho g_\theta-\frac{1}{r}\frac{\partial p}{\partial \theta}+\mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial V_\theta}{\partial r}\right)-\frac{V_\theta}{r^2}+\frac{1}{r^2}\frac{\partial^2 V_\theta}{\partial \theta^2}+\frac{2}{r^2}\frac{\partial V_r}{\partial \theta}+\frac{\partial^2 V_\theta}{\partial z^2}\right]$$
$$=\rho\left(\frac{\partial V_\theta}{\partial t}+V_r\frac{\partial V_\theta}{\partial r}+\frac{V_\theta}{r}\frac{\partial V_\theta}{\partial \theta}+\frac{V_r V_\theta}{r}+V_z\frac{\partial V_\theta}{\partial z}\right)$$

z-component:
$$\rho g_z-\frac{\partial p}{\partial z}+\mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial V_z}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 V_z}{\partial \theta^2}+\frac{\partial^2 V_z}{\partial z^2}\right]$$
$$=\rho\left(\frac{\partial V_z}{\partial t}+V_r\frac{\partial V_z}{\partial r}+\frac{V_\theta}{r}\frac{\partial V_z}{\partial \theta}+V_z\frac{\partial V_z}{\partial z}\right)$$

Energy Equation

Cartesian coordinates

$$\rho c_v\left(\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}\right)=k\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right)$$
$$+2\mu\left[\left(\frac{\partial u}{\partial x}\right)^2+\left(\frac{\partial v}{\partial y}\right)^2+\left(\frac{\partial w}{\partial z}\right)^2\right]$$
$$+\mu\left[\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)^2+\left(\frac{\partial u}{\partial z}+\frac{\partial w}{\partial x}\right)^2+\left(\frac{\partial v}{\partial z}+\frac{\partial w}{\partial y}\right)^2\right]$$

Scratch paper - You can remove this section from the test sheets.

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