 Student ID............................

PRINCE OF SONGKLA UNIVERSITY

FACULTY OF ENGINEERING

Midterm Examination Semester II (Part I) Academic Year: 2004

Date: Dec 19, 2004 Time: 13.30 – 16.30

Subject: 230-630 Advanced Transport Phenomena I Room: R300

Instructions

- Students are allowed to bring only the text book "Transport Phenomena (Bird, Stewart & Lightfoot)" to the exam room.
- No exams are allowed to leave the room.
- Students are allowed to use a pen or pencil.

Name .... **Student ID** ....

ชื่อ ....รหัส..................................

Problem No.	**1**	**2**	**3**	**4**	**5**	**Total**
Points	**25**	**25**	**30**	**20**	**20**	**120**
Score						

Exam Prepared by

Dr. Chayanoot Sangwichien

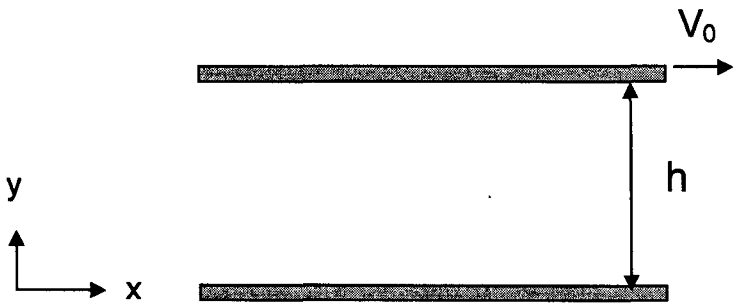
13 December 2004

ทุจริตการสอบ โทษขั้นต่ำคือปรับตกในรายวิชาที่ทุจริตและพักการเรียน 1 ภาคการศึกษา

Total of 8 Pages (including the cover sheet)

Problem 1 (25 points)

Water flows between two parallel plates, a distance **h** apart. The upper plate moves at velocity $\mathbf{V_0}$, the lower plate is stationary. For what values of pressure gradient $\left(\frac{dP}{dx}\right)$ will the shear stress $\left(\tau_{yx}\right)$ at the lower wall be zero?



Note: Solve this problem by using the equation of change

Problem 2 (25 points)

Consider fully-developed laminar flow in a horizontal circular pipe. Using the equation of continuity and motion, develop an expression for the velocity distribution of a **non-Newtonian fluid** with properties that can be represented by the power-law model. The velocity profile should be described in terms of the pressure difference across the pipe, the dimensions of the pipe (length:L, radius:R), and the fluid properties.

"Power-Law Model" $\tau_{rz} = -m\left(\frac{dv_z}{dr}\right)^n$

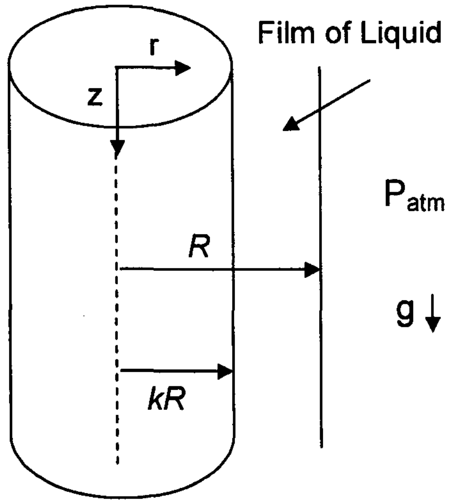
Problem 3 (30 points)

A Newtonian, incompressible fluid is flowing down the outside of a cylinder of thickness κR. The fluid flowing down the outside of the cylinder has a thinkness of R - κR and is exposed to atmospheric pressure everywhere. The fluid has a density, ρ, and a viscosity, μ. You may neglect end effects. Solve for the velocity profile $v_z(r)$ for laminar flow down the outside of the solid cylinder by the following steps.

(a) List all assumptions and simplify the z-component of the equations of motion to a differential equation. Explain why you can remove each term to simplify the equation.

(b) State your boundary conditions.

(c) Solve the equation using the boundary conditions to find $v_z(r)$.

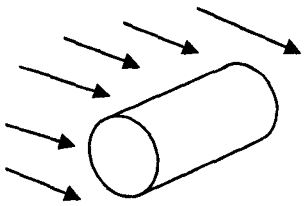


Problem 4 (20 points)

The flow **past** a long cylinder is very different from the flow past a sphere. It is found that when the fluid approaches with a velocity v_∞, the kinetic force acting on a length L of the cylinder is

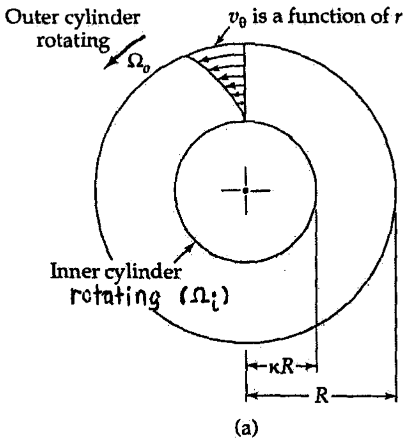
$$F_k = \frac{4\pi\mu v_\infty L}{\ln(7.4/\mathrm{Re})}$$

The cylinder has a diameter of D. What is the formula for the friction factor as a function of the Reynolds number?



Problem 5 (20 points)

The fluid is at rest for t < 0. Starting at t = 0 the outer cylinder begins rotating with a constant angular velocity to cause laminar flow for t > 0. Rewrite the Navier-Stokes equation, I.C. and B.C. for the unsteady tangential flow in an annulus.



BIRD: *Transport Phenomena, 2e*
Fig. 3.6-1 W-38

It is convenient to introduce the following dimensionless variables:

$$\xi = \frac{r}{R} \qquad \tau = \frac{\mu t}{\rho R^2}$$

$$\Phi = \frac{v_\theta}{R(\Omega_o - \Omega_i)} \qquad -\alpha = \frac{\Omega_i}{(\Omega_o - \Omega_i)}$$

The equation of motion for $v_\theta(r,t)$ is

$$\rho \frac{\partial v_\theta}{\partial t} = \mu \frac{\partial}{\partial r}\left[\frac{1}{r}\frac{\partial}{\partial r}(r v_\theta)\right]$$