Code No. \_

**Fluid Mechanics Ph.D Qualifier Exam**

Depart ment of l\Iechanical Engineering Michigan State University

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Directions: Closed book

All problems carry equal weight. In order to receive full credit for a solution, you must show all work clearly.

Exam prepared by Profs. **P.** Lillehoj and G. Brereton

Stokes flow (also called creeping flow) is a fluid flow at very low Reynolds number *( Re* << 1) and can be used to describe the movement of aerosol particles and microorganisms. The drag force *FD* on an object in a creeping flow is a function of its velocity *V ,* a characteristic length scale *L* of the object and the fluid viscosity *µ.*

1. Using t he Pi theorem, find the dimensionless parameters t hat describe a relationship for

*FD* as a function of the independent variables, showing your work.

1. Consider a water flee 1 mm in diameter. A 100x full scale model is tested in glycerin *( µ* 1.5 kg/m.s) at *V* 30 cm/s. If the measured drag force on the model is 1N, what is the drag force of the actual '\Nater flee if it moves at 2 cm/s in water (µ = 0.001 kg/m.s)?

A nozzle (3 cm in diameter) connected to a fire hose is held by firefighters with water *( p* = 998 kg/m3 ) flowing at 2 m3/min at an angle of 30° to the horizontal. Assume the flow is steady and incompressible.

1. Determine the average water exit velocity (in m/s).
2. Calculate the horizontal force (in N) exerted on t he firefighters by the water jet. Neglect frictional effects and minor losses.

The differential .T-moment um equation for steady, fully developed, incompressible flow of a Newtonian fluid in a two-dimensional Cartesian inertial frame is

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0 = *---*>:. *+ !T + v* 5:i 0

*p ux uy*

where *f r* is the body force in the ;T-direction. Consider the problem of a liquid layer of thickness *h* flowing down a long flat vertical surface under gravity. The outside of the sheet is exposed to air at atmospheric pressure.

1. \Vhat are t he boundary conditions on *u?*
2. Find an expression for *u* as a function of *y .*
3. At what value of *y* is *u* equal to its average value?

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\¥ater flows up the inclined (at 30° ) pipe as shown. If the volumetric flow rate is 0.02 111 /s, determine t he height *h* to which the water will rise in the pitot tube.

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The container shown is filled with water and kerosine to the depths given. What mass *Ai*

is required to keep the gate in place? Assume *Pwatcr* 1000 kg/m3 and *Pk cr* = 814 kg/m3 .

