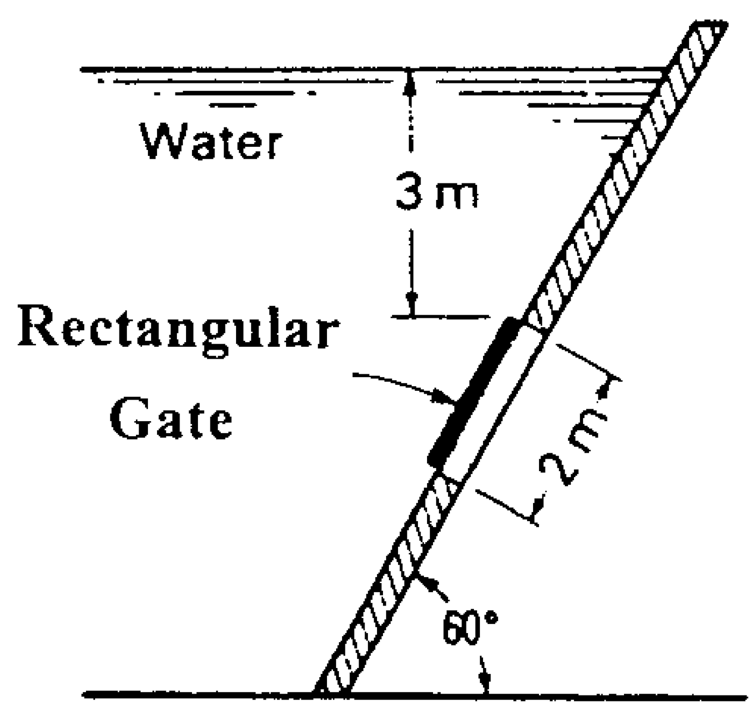
國立臺灣科技大學
九十學年度碩士班招生考試試題

系所組別： 機械工程系丙組
科　　目： 流體力學

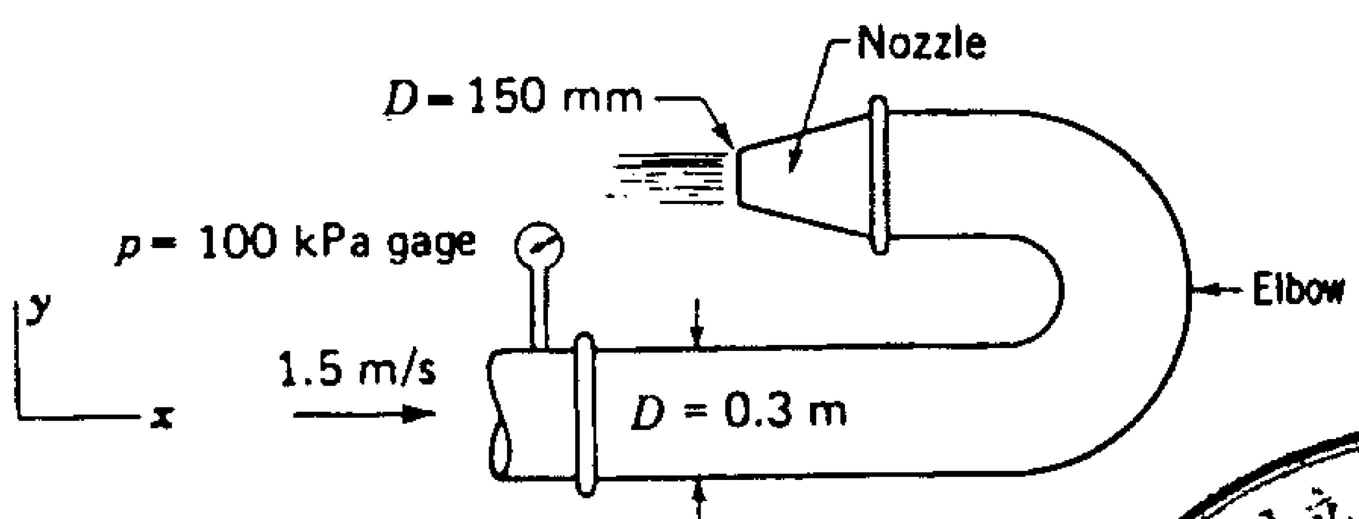
Note: 1. Each problem is 20 points.
2. All the governing equations and properties needed are listed in page 3.

1. The velocity field of a flow is given by $\vec{V} = x\,\hat{i} + x(x-1)(y+1)\,\hat{j}$.
   (a) Is it an incompressible flow ? Justify your answer. (5%)
   (b) Is it an irrotational flow ? Justify your answer. (5%)
   (c) Determine the streamline that passes through $x = 0$ and $y = 0$. (5%)
   (d) Determine the pathline that passes through $x = 1$ and $y = 1$. (5%)

2. Find the magnitude and point of application of the force on the rectangular gate $2m$ by $1m$ shown in the figure. (20%)



3. What is the force on the elbow-nozzle assembly from the water and air ? The water issues out as a free jet from the nozzle. The interior volume of the elbow-nozzle assembly is $0.1\,m^3$. (20%)



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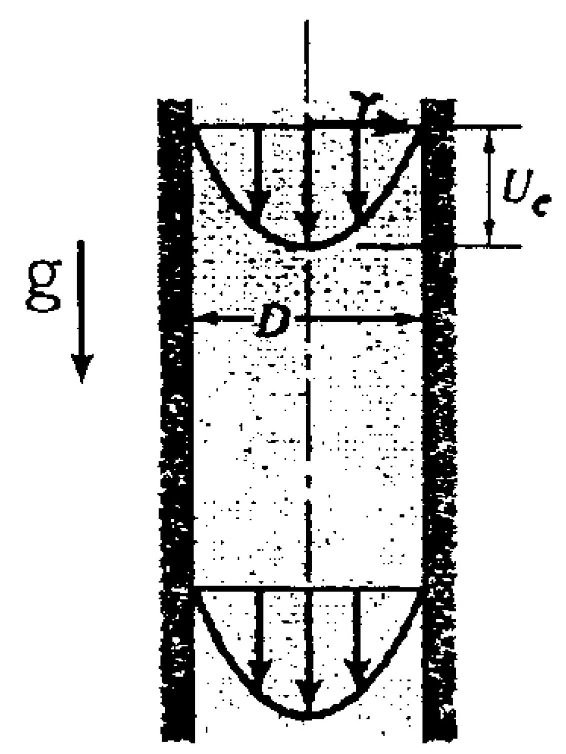
4. Water of density ρ and viscosity μ flows steadily vertically down a circular tube of diameter D, as shown in the figure. The flow is fully developed, and it has a parabolic velocity profile given by $\frac{u}{U_c} = 1 - \left(\frac{2r}{D}\right)^2$, where the maximum velocity is U_c, and the other notation is given in the figure.
   (a) Find the shear stress acting at the wall in terms of the density ρ, the gravitational constant g, and the diameter D.
   (b) Express the kinematic viscosity in terms of D, U_c, and g. (20%)



5. Air flows steadily and isentropically through a convergent-divergent nozzle at 100 *kg/sec*. At one section where $A = 0.464\ m^2$, $M = 3$, $T = -60\ ^\circ C$, and $p = 15.0$ *kPa* (*abs*). Determine the speed and cross-sectional area downstream where $T = 138\ ^\circ C$. (20%)

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Properties:

$g = 9.81 m/s^2$

$\rho_{water} = 1000 kg/m^3$

gas constant for air, $R = 287 N \cdot m / kg \cdot K$

specific heat ratio for air, $k = 1.4$

Equations:

For isentropic flow of an ideal gas,

$pv^k = const.$

$$\frac{T_0}{T} = 1 + \frac{k-1}{2} M^2$$

$$\frac{P_0}{P} = \left[1 + \frac{k-1}{2} M^2\right]^{k/(k-1)}$$

Equation of state

$$pv = RT$$

Speed of sound

$$c = (kRT)^{1/2}$$

Continuity Equation:

$$0 = \frac{\partial}{\partial t}\int_{cv} \rho d\forall + \int_{cs} \rho \vec{V} \cdot d\vec{A}$$

$$\nabla \cdot \rho \vec{V} + \frac{\partial \rho}{\partial t} = 0 \quad \text{or} \quad \frac{D\rho}{Dt} + \rho div \vec{V} = 0$$

Momentum Equation:

$$\vec{F}_S + \vec{F}_B - \int_{CV} \left[\vec{a}_{rf} + 2\vec{\omega} \times \vec{V}_{xyz} + \vec{\omega} \times (\vec{\omega} \times \vec{r}) + \dot{\vec{\omega}} \times \vec{r}\right] \rho d\forall$$

$$= \frac{\partial}{\partial t}\int_{CV} \vec{V}_{xyz} \rho d\forall + \int_{CS} \vec{V}_{xyz} \rho \vec{V}_{xyz} \cdot d\vec{A}$$

$$\rho \frac{D\vec{V}}{Dt} = -\nabla p + div\, \vec{\tau} + \rho \vec{g}$$

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