BITS, PILANI-DUBAI CAMPUS, KNOWLEDGE VILLAGE, DUBAI

Second Semester 2006-2007

CHE UC213 Fluid Flow Operations

Comprehensive Examination

(Closed Book)

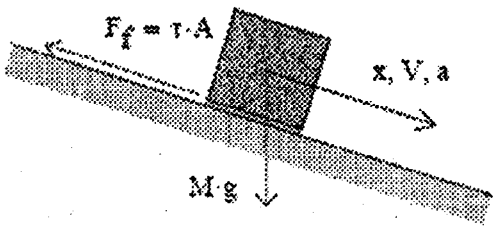
DATE: 20-05-07

DURATION: 3 hours MAXIMUM MARKS: 120

Instructions:

1. Attempt ALL questions.
2. Make suitable assumptions wherever necessary and state them clearly.
3. Be brief and precise. Illegibility will cost you marks.
4. Some useful data and correlations are given at the end of question paper.
5. Assume missing data, if any, reasonably.

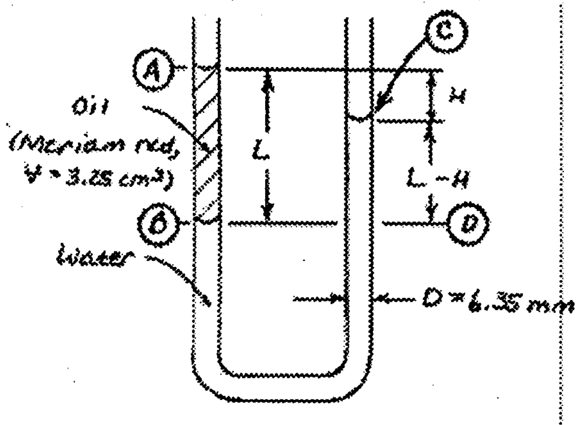
1. A block 0.2 m square, with 5 kg mass, slides down a smooth incline, 30^{0} below the horizontal, on a film of oil that is 0.20 mm thick.
   (a) If the block is released from rest at t = 0, what is its initial acceleration, given viscosity of oil = 0.4 N.s/m^2.
   (b) Derive an expression for the speed of the block as a function of time. Find the speed after 0.1 s.
   (c) If we want the mass to instead reach a speed of 0.3 m/s at this time, find the viscosity of the oil we would have to use. [15]



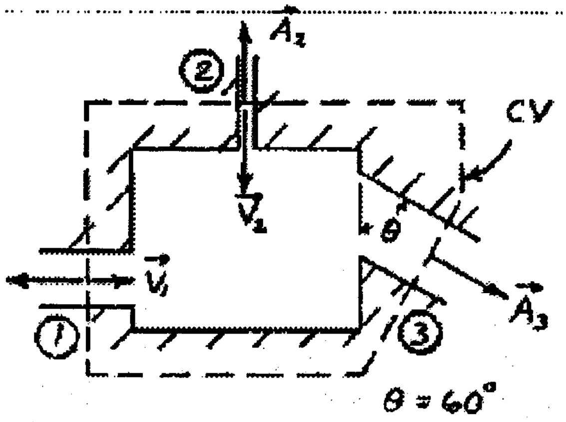
2. A hollow metal cube with sides 100 mm each floats at the interface between a layer of water and a layer of SAE 10W oil such that 10% of the cube is exposed to the oil. Find out
   (a) The pressure difference between the upper and lower horizontal surfaces?
   (b) The average density of the cube?
   Data given: specific gravity of SAE 10W oil = 0.92 [10]

3. (a) Small gas bubbles form in soda when a bottle is opened. The average bubble diameter is about 0.1 mm. Estimate the pressure difference between the inside and outside of such a bubble. Given surface tension = 72.8 X 10^{-3} N/m [05]

(b) A manometer is formed from glass tubing with uniform inside diameter, D = 6.35 mm. the U-tube is partially filled with water. Then, 3.25 m^3 of red oil is added to the left side. Calculate the equilibrium height, H, when both legs of the U-tube are open to the atmosphere. Given: specific gravity of red oil = 0.827 [08]



4. Fluid with 1050 kg/m^3 density is flowing steadily through the rectangular box as shown in figure. Given A_1 = 0.05 m^2, A_2 = 0.01 m^2, A_3 = 0.06 m^2, $\vec{V}_1 = 4\hat{i}$ m/s, and $\vec{V}_2 = 8\vec{j}$ m/s, determine the velocity $\vec{V}_3$. [10]



5. The velocity distribution in a two-dimensional steady flow field in the xy plane is $\vec{V} = (Ax - B)\hat{i} + (C - Ay)\hat{j}$ where A = 2 s^{-1}, B = 5 m.s^{-1}, and C = 3 m.s^{-1}; the coordinates are measured in meters, and the body force distribution is $\vec{g} = -g\hat{k}$.

(a) Does the velocity field represent the flow of an incompressible fluid?
(b) Find the stagnation point of the flow field.
(c) Obtain an expression for the pressure gradient in the flow field.
(d) Evaluate the difference in pressure between point (x, y) = (1, 3) and the origin, if the density is 1.2 kg/m^3.

[03+03+04+05=15]

6. Consider the flow field represented by the velocity potential $\phi = Ax + Bx^2 - By^2$, where $A = 1\ m.s^{-1}$, $B = 1\ s^{-1}$, and the coordinates are measured in meters.

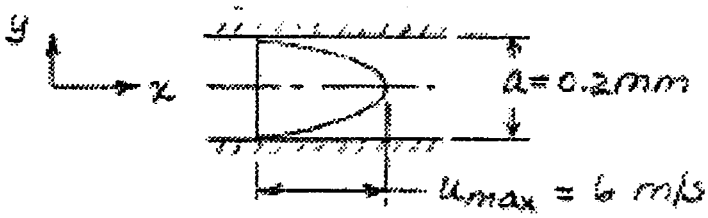
   (a) Obtain expressions for the velocity field and the stream function.

   (b) Calculate the pressure difference between the origin and the point (x, y) = (1, 2).

   Given: density of fluid = 999 kg/m^3 [03+03+04=10]

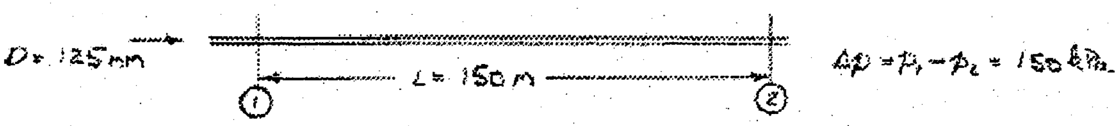
7. The diameter, d, of bubbles produced by a bubble-making toy depends on the soapy water viscosity, μ, density, ρ, and surface tension, σ, the ring diameter, D, and the pressure differential, Δp, generating the bubbles. Use dimensional analysis to find the PI parameters that characterize this phenomenon. Take ρ, D, and Δp as repeating parameters. [10]

8. (a) Consider the fully developed laminar flow of water between stationary parallel plates. The maximum flow speed, plate spacing, and width are 6 m/s, 0.2 mm, and 30 mm, respectively. Find the kinetic energy coefficient, α. [10]



   (b) Water flows steadily in a horizontal 125 mm diameter cast-iron pipe. The pipe is 150 m long and the pressure drop between sections (1) and (2) is 150 kPa. Find the volume flow rate through the pipe.

   Given: surface roughness of pipe = 0.26 mm, kinematic viscosity of water = 1.14 X 10^{-6} m^2/s [15]



9. (a) A photograph of a bullet shows a mach angle of 32°. Determine the speed of bullet for standard air. [05]

   (b) A body moves through standard air at 200 m/s. what is the stagnation pressure on the body? Assume (i) incompressible flow, and (ii) compressible flow.

   Given: for standard air, k = 1.4, R = 287 N.m/kg.K, P = 101 kPa, T = 15 °C, ρ = 1.225 kg/m^3 [02+05]

*** Best of luck ***

Some useful equations:

Bulk compressibility modulus $E_v = \dfrac{dP}{\left(\frac{d\rho}{\rho}\right)}$

Conservation of mass, incompressible flow,

$$\int_{CS} \vec{V} \cdot d\vec{A} = 0$$

Conservation of mass, steady, compressible flow,

$$\int_{CS} \rho\vec{V} \cdot d\vec{A} = 0$$

Continuity equation

$$\nabla \cdot \rho\vec{V} + \frac{\partial \rho}{\partial t} = 0$$

Differential equation for conservation of mass $\dfrac{\partial u}{\partial x} + \dfrac{\partial v}{\partial y} = \dfrac{\partial^2 \psi}{\partial x \partial y} - \dfrac{\partial^2 \psi}{\partial y \partial x} = 0$

The irrotationality condition $\nabla X \vec{V} = 0$

Potential function $\vec{V} = -\nabla \phi$

Laplace equations $\dfrac{\partial^2 \psi}{\partial x^2} + \dfrac{\partial^2 \psi}{\partial y^2} = 0, \qquad \dfrac{\partial^2 \phi}{\partial x^2} + \dfrac{\partial^2 \phi}{\partial y^2} = 0$

Reynolds Transport Theorem

$$\left.\frac{dN}{dt}\right)_{\text{system}} = \frac{\partial}{\partial t}\int_{CV} \eta \rho \, d\forall + \int_{CS} \eta \rho \vec{V} \cdot d\vec{A}$$

Fluid particle acceleration

$$\frac{D\vec{V}}{Dt} \equiv \vec{a}_p = \left(\vec{V}.\nabla\right)\vec{V} + \frac{\partial \vec{V}}{\partial t}$$

Euler's equation

$$\rho \frac{D\vec{V}}{Dt} = \rho\vec{g} - \nabla p$$

The universal velocity profile

Laminar sublayer : $0 < y^+ < 5 : u^+ = y^+$

Buffer Layer : $5 < y^+ < 30 : u^+ = 5.0 \ln y^+ - 3.05$

Turbulent Layer : $30 < y^+ < 400 : u^+ = 2.5 \ln y^+ + 5.5$

Kinetic energy coefficient $\alpha = \dfrac{\int_A \rho V^3 dA}{\dot{m}\bar{V}^2}$

Head loss in turbulent flow, $h_l = f \dfrac{L}{D}\dfrac{\bar{V}^2}{2}$

Friction factor correlation:

$$\frac{1}{\sqrt{f}} = -1.737 \ln\left(\frac{5.72}{Re^{0.9}} + \frac{\varepsilon/D}{3.707}\right)$$

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Second Semester 2006-2007

CHE UC213 Fluid Flow Operations

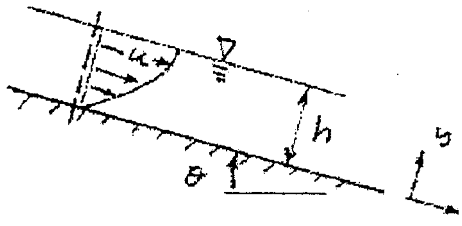
TEST – 2 (Open Book)

DATE: 08-04-07

DURATION: 50 MINUTES MAXIMUM MARKS: 60

Note: Attempt ALL questions. Clearly show all calculation steps.

1. (a) Oil flows steadily in a thin layer down an inclined plane. The velocity profile is: $u = \frac{\rho g \sin\theta}{\mu}\left[hy - \frac{y^2}{2}\right]$. Express the mass flow rate per unit width in terms of $\rho, \mu, g, \theta, \text{and } h$. [10]

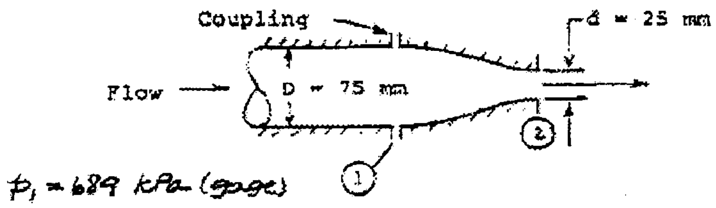


(b) A cylindrical tank of 0.3 m diameter drains through a hole in its bottom. At the instant when the water depth is 0.6 m, the flow rate from the tank is observed to be 4 kg/s. Determine the rate of change of water level at this instant. [10]

2. (a) Consider the flow field represented by the stream function $\psi = \left(\frac{q}{2\pi}\right)\tan^{-1}\left(\frac{y}{x}\right)$, where q = constant. Is this a possible two-dimensional, incompressible flow? Is the flow irrotational? [4+4]

(b) A steady, two-dimensional velocity field is given by $\vec{V} = Ax\hat{i} - Ay\hat{j}$, where A = 1 s^{-1}. Derive the expression for the streamlines. Obtain a general expression for the acceleration of a fluid particle in this velocity field. Calculate the acceleration of the particles at the points (x, y) = (1/2, 2) and (1, 1). [12]

3. (a) A fire nozzle is coupled to the end of a hose with inside diameter D = 75 mm. the nozzle is contoured smoothly and has outlet diameter d = 25 mm. The design inlet pressure for the nozzle is P_1 = 689 kPa (gage). Calculate the maximum volumetric flow rate the nozzle could deliver. [10]



(b) A flow field is represented by the stream function $\psi = x^2 - y^2$. Find the corresponding velocity field. Show that this field is irrotational and obtain the potential function. [10]

*** GOOD LUCK ***

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Second Semster 2006-2007

CHE UC213 Fluid Flow Operations

TEST - 1

(Closed Book)

DATE: 28-02-07

DURATION: 50 MINUTES **MAXIMUM MARKS: 60**

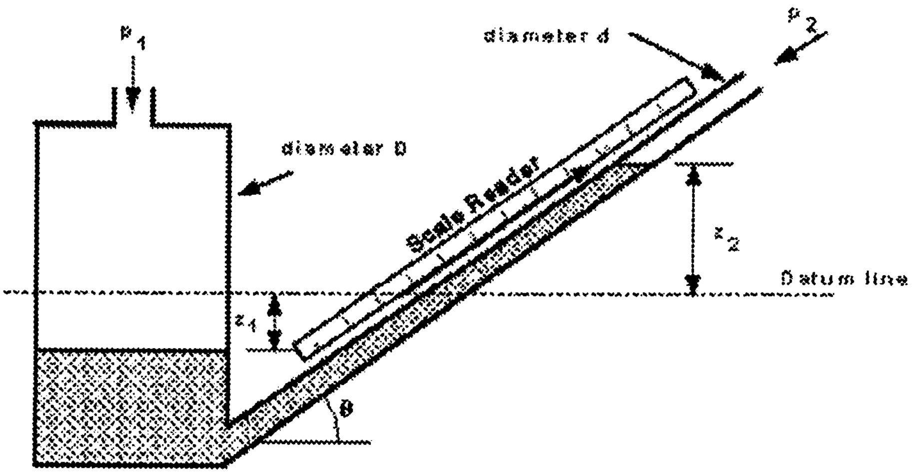
Note: Attempt ALL questions.

1. For the velocity field $\vec{V} = Axy\hat{i} + By^2\hat{j}$, where A = 1 $m^{-1}s^{-1}$, B = -0.5 $m^{-1}s^{-1}$, obtain an equation for the streamlines. [10]

2. Give a brief classification of fluids based on viscosity. Show their shear stress – shear rate relationships graphically. [20]

3. Briefly discuss the concept of boundary layer. How it differs in internal flow from that in internal flow? [10]

3. An inclined tube reservoir manometer is shown in the figure. For this manometer, obtain an expression for calculating the liquid deflection L in the inclined tube, in terms of applied pressure difference (P_1 – P_2), manometer geometric parameters D, d and θ, and specific gravity of the manometer fluid. [20]



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BITS, PILANI-DUBAI CAMPUS, KNOWLEDGE VILLAGE, DUBAI

Second SEMESTER 2006-2007

CHE UC213 Fluid Flow Operations

Quiz - 1

(Closed Book)

DATE: 07-03-07

DURATION: 30 MINUTES **MAXIMUM MARKS: 30** **WEIGHTAGE: 10%**

Name of the student: --------------------------- I.D.: ---------------------------

Answers

(Write either a, b, c or d in the space provided. Change of answer and overwriting is not permitted, so be sure before entering your answer)

1	2	3	4	5	6	7	8	9	10

11	12	13	14	15	16	17	18	19	20

***Important Note*: Questions 1 to 10 are ONE Mark each; questions 11 to 20 are TWO marks each.**

1. A fluid is a substance that
   (a) always expands until it fills any container
   (b) is practically incompressible
   (c) deforms continuously when subjected to a shear stress
   (d) can not be subjected to shear stress

2. Units of dynamic viscosity are
   (a) kg-s^2/m (b) kg/m-s^2 (c) N/m-s (d) kg/m-s

3. Kinematic viscosity is
   (a) viscosity / density (b) viscosity X density
   (c) viscosity X specific weight (d) viscosity/ specific weight

4. An ideal fluid
   (a) has constant viscosity (b) has zero viscosity
   (c) satisfies only PV = RT (d) has time-independent viscosity

5. The continuum assumption is valid
   (a) when the system size is very large as compared to the mean free path of the molecules

(b) when the system size is comparable to the mean free path of the molecules
(c) when the system size is less the size of a molecule
(d) always and it does not depend on the size of the system.

6. In steady state
   (a) properties vary linearly with location in space
   (b) properties are not a function of time
   (c) properties are not a function of space coordinates
   (d) properties vary linearly with time

7. For a fluid flowing over a flat plate, the change from laminar to turbulent flow is encountered for
   (a) Re < 2300 (b) Re < $5X10^5$ (c) Re > 2300 (d) Re > $5X10^5$

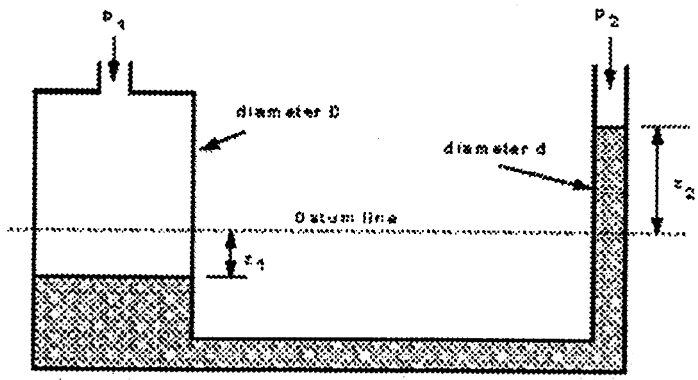
8. In fluid dynamics, gas flows can be considered as incompressible when
   (a) Mach number is equal to zero
   (b) Mach number is less than 0.3
   (c) Mach number is less than 1.0
   (d) Mach number is equal to 1.0.

9. For the velocity field $\vec{V} = a(x^2 + y^2)^{0.5}\left(1/z^3\right)\hat{k}$ the flow is
   (a) one-dimensional steady (b) three-dimensional steady
   (c) two dimensional steady (d) two-dimensional unsteady

10. Froude number is the ratio of
   (a) inertial and viscous forces
   (b) inertial and gravity forces
   (c) gravity force and surface tension
   (d) speed of fluid and speed of sound

11. The pressure of 500 kN can be expressed in terms of head of water column as
   (a) 5.1 m of water (b) 51 m of water
   (c) 3.75 m of water (d) 34 m of water

12. For the manometer shown in the figure, the pressure drop $P_1 - P_2$ is given by the equation



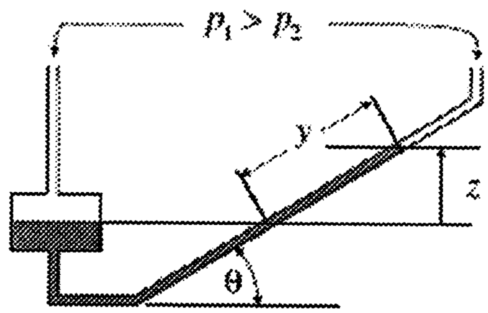
(a) $P_1 - P_2 = \rho g z_1\left[1 + \left(\frac{d}{D}\right)\right]$ (b) $P_1 - P_2 = \rho g z_1\left[1 + \left(\frac{d}{D}\right)^2\right]$

(c) $P_1 - P_2 = \rho g z_2 \left[1 + \left(\frac{d}{D}\right)\right]$ (d) $P_1 - P_2 = \rho g z_2 \left[1 + \left(\frac{d}{D}\right)^2\right]$

13. for the inclined tube manometer shown in the figure below, the pressure difference is given by the equation

(a) $P_1 - P_2 = \rho g z \sin\theta$ (b) $P_1 - P_2 = \rho g z \cos\theta$

(c) $P_1 - P_2 = \rho g y \cos\theta$ (d) $P_1 - P_2 = \rho g y \sin\theta$



$$\tau = K\left(\frac{\partial u}{\partial y}\right)^n$$

14. In the equation

(a) K is apparent viscosity and n is consistency index
(b) K is flow behavior index and n is consistency index
(c) K is apparent viscosity and n is flow behavior index
(d) K is consistency index and n is flow behavior index

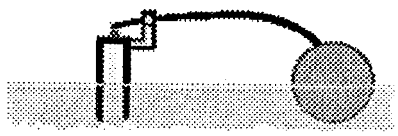
15. Consider the following statements:

i) Pseudoplastics are shear-thinning fluids
ii) Newtonian fluids have viscosity independent of temperature
iii) Thixotropic fluids show a decrease in apparent viscosity with time under constant applied stress.
iv) Dilatant fluids need a minimum initial stress to start flowing

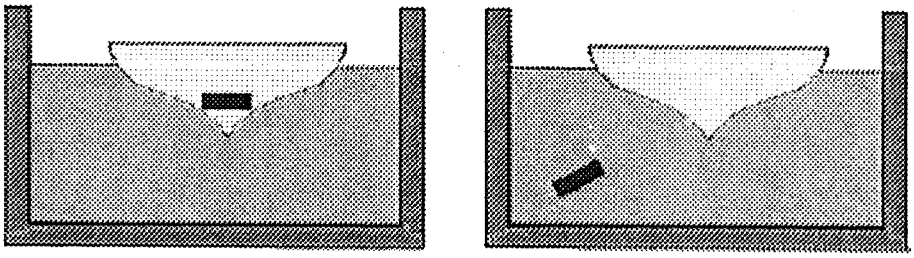
(a) Statements (i) and (ii) are correct
(b) Statements (i) and (iii) are correct
(c) Statements (iii) and (iv) are correct
(d) Statements (i) and (iv) are correct.

16. The float in a toilet tank is a sphere of diameter 10 cm. What is the buoyancy force on the float when it is completely submerged?

(a) 5.1 N (b) 51 N
(c) 510 N (d) 5.1 kN



17. You are floating in a small dingy in your pool (see figure). There's a brick in the boat. You toss the brick out of the boat and into the pool. The brick sinks to the bottom of the pool. Does the water level at the side of the pool rise, stay the same, or decrease?

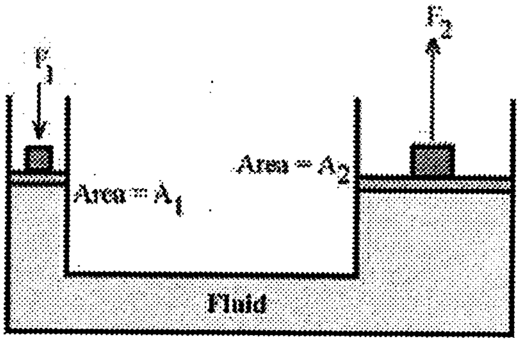


(a) Level falls (b) Level rises (c) Level remains the same
(d) Level will fall or rise depending the temperature of water

18. For the figure shown below, the correct relationship is

(a) $F_2 = \left(A_1/A_2\right)F_1$ (b) $F_2 = \left(A_2/A_1\right)F_1$

(c) $F_2 = A_2 A_1 F_1$ (d) $F_2 = \left(\frac{1}{A_1}+\frac{1}{A_2}\right)F_1$



19. A metal object has a mass of 10 g in air and an apparent mass (due to buoyancy) of 6 g in water. What is the density of the metal?

(a) 10 g/cm³ (b) 4 g/cm³ (c) 2.5 g/cm³ (d) 6 g/cm³

20. A hollow metal cube with sides 100 mm floats at the interface between a layer of water and oil such that 20% of cube is exposed to oil. If water density is 1000 kg/m³ and oil density is 900 kg/m³, the average density of cube will be
(a) 950 kg/m³ (b) 980 kg/m³ (c) 990 kg/m³ (d) 1000 kg/m³

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