Kaferelsheikh University
Faculty of Engineering
Department of Mechanical Engineering
Year: 2015-2016
2nd year MPE Bylaw2007

Subject: Fluid Mechanics
Date: 21/05/2016
Time allowed: 3hr
Full Mark: 60
Final Exam: 3 pages + charts

Assume any missing data, state your assumption clearly

Answer all questions

Question: 1 **[20 marks]**

(a) Drive an expression for the continuity equation in three dimensional cylindrical coordinate. [5 marks]

(b) The velocity field of a flow is given by: $V = (6xy + 5xt)i - 3y^2 j + (7xy^2 - 5zt)k$

Determine: i) Is the flow incompressible? ii) the acceleration component in y-direction, and iii) the pressure gradient $\partial p / \partial y$ of a particle at x=2m, y=-1 m, and z=4 m and t=1 sec. Take: $\mu = 0.001$ Pa.s, ρ =1000 Kg/m^3, g_y=5 m/s^2. [5 marks]

(c) A conveyor-belt device, illustrated in Fig. 1 is mounted on a ship and used to pick up undesirable oil from the surface of the sea. Assume the oil film to be thick enough for the supply to be unlimited with respect to the operation of the device, and that the pressure is constant throughout the film. Assume also the belt to operate at a steady velocity "U" and to be long enough for a uniform flow depth 'h' to exist. Find:

i) Starting from N.S.E. with the appropriate boundary conditions, determine the flow rate at which oil is carried up the belt per unit width in term of θ, U, and the oil properties μ and γ. [4 marks]

ii) The flow rate if U=1 m/s, h=6 mm, μ=0.8 poise, specific gravity of oil =0.8 and $\theta = 30^0$. [3 marks]

iii) The flow depth 'h' at which the net picked up oil tends to zero and explain why 'h' cannot be increased more than that depth. [3 marks]

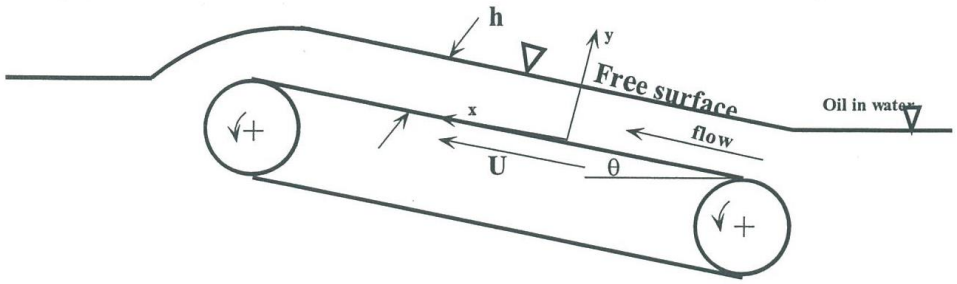

Fig.1

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Question: 2 [18 marks]

(a)The velocity profile for turbulent flow through a smooth pipe is represented by $\frac{v}{u_{max}} = (1-\frac{r}{R})^{\frac{1}{n}}$. Show that the ratio of average velocity ($\bar{v}$) to the maximum velocity (u_{max}) is given by $\frac{\bar{v}}{u_{max}} = \frac{2n}{(n+1)(2n+1)}$ where n is the exponent; r is radius of the pipe; R is outer radius of pipe. [5 marks]

b) Sketch: the velocity profile and the shear stress profile for fully –developed laminar flow between to horizontal parallel plates one fixed and the other moving with velocity of u for pressure gradients of $\partial p/\partial x = 0, \partial p/\partial x \prec 0, \partial p/\partial x \succ 0$ [3 marks]

c) An oil with ρ=900 kg/m^3 and ν=0.0002 m^2/s flows upward through a vertical pipe of 6 cm diameter and 15 m length. The volumetric flow rate through the pipe is 5.654 liter/s. The pressure at the inlet of the pipe is 600 kPa. Estimate: i) the pressure gradient ($\partial p/\partial z$) and the pressure at the outlet of the pipe, ii) the maximum velocity and the velocity at r=1 cm from the center of the pipe, and iii) the shear stress at the pipe wall. [10 marks]

Question: 3 [10 marks]

a) In some speed ranges, vortices are shed from the rear of bluff cylinders placed across a flow. The vortices alternately leave the top and bottom of the cylinder, as shown in Fig. 2. The vortex shedding frequency, *f*, is thought to dependent on fluid density, ρ, and viscosity, μ, cylinder diameter, d, and free-stream velocity, V. (a) Use dimensional analysis to develop a functional relationship for *f*. (b) Vortex shedding occurs in standard air on two cylinders with diameters d_m and d_p, respectively. If the diameter ratio is $d_p/d_m = 2$, determine the velocity ratio, V_p/V_m, for dynamic similarity, and the ratio of vortex shedding frequencies, f_p/f_m. For part (a), use the MLT unit system. [4 marks]

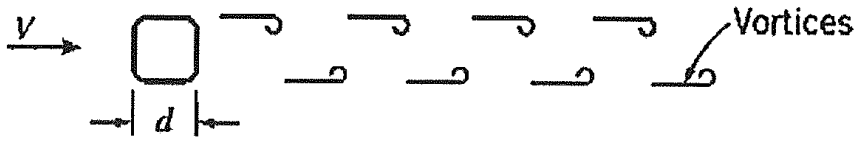

Fig. 2

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b) Show diagrammatically the development of boundary layer over a flat plate in uniform flow at zero incidence showing one velocity profile in both laminar and turbulent flow regions and define : $\delta, \delta^*, \theta, H_{12}, C_f$ and C_D. [3 marks]

c) A thin flat plate 40 by 80 cm is immersed in a stream of water, (ρ=1000 [kg/m^3], $\nu=10^{-6}$ [m^2/s]), at a velocity 2.5 m/s. Compute using Blasius result for laminar boundary layer $\delta, \delta^*, \theta, H_{12}, C_f$ and C_D at the plate end and the plate viscous drag in Newton's if the plate side parallel to the stream is the short side. Assume $Re_{crit}=10^6$. [3 marks]

Question: 4 [12 marks]

(a)Give reasons for Golf ball is damped? [3 marks]

(b) A chimney for thermal power plant is 3 m diameter and 60 m length. Calculate the bending moment at the chimney base when a wind of 1.5 m/s blowing. Also establish whether the chimney is likely to be subjected to forced vibration and if so what would be the frequency? (Take for air ρ=1.155 [kg/m^3], $\mu=13\times10^{-6}$Pa.s) [3 marks]

c) Aircraft with the following specifications: Weight, 13620 N, wing span, 10 m wing chord, 3 m, take off speed 108 km/hr, atmospheric condition P=100 kPa, and T=27 c, R_{air}=0.287 kj/kg.k, $C_L=0.35(1+0.2\alpha)$, $C_D=0.008(1+\alpha)$ where α is an angle of attack in degree. Find out: i) α for takeoff and ii) power required for takeoff in horse power. [3 marks]

d) A solid sphere of a specific gravity 2.4 when dropping in oil of specific gravity 0.9 and viscosity 0.0027 Pa.s attains a terminal velocity of 3 m/s. Assume Stokes flow calculate the diameter of the sphere. The density and viscosity of air are ρ=1.3 [kg/m^3], $\mu=1.7\times10^{-5}$Pa.s) respectively, Assume: $C_D = 18.5/R_e^{0.6}$. [3 marks]

GOOD LUCK

Dr. Ismail Mohamed Sakr