Kafrelsheikh University
Faculty of Engineering
Dept. Mech. Engineering
Year: 2nd Year Mechanical
Subject: Fluid Mechanics (MEP2005)

Semester: 2nd Semester
Final Examination
Date: May 24th, 2018
Time allowed: 3 hours
Full Mark: 60

(a) This exam measures ILOs no.: a13, b1, b2, b3, c1, c18& d7.
(b) No. of questions: 4- No. of pages: 3
(c) This is a close book exam. ***Non-programmable calculators*** are allowed.
(d) Clear, systematic answers and solutions are required. In general, marks will not be assigned for answers and solutions that require unreasonable (in the opinion of the instructor) effort to decipher.
(e) Ask for clarification if any question statement is not clear to you.
(f) Attempts in all questions.
(g) The weight of each problem is indicated.
(h) The exam will be marked out of 60. There are 6 marks bonus.

Question 1 (7+5 = 12) Marks ILOs no.: b1, b2, b3, c18& d7

a. A one-twelfth-scale model of an airplane is to be tested at 20°C in a pressurized wind tunnel. The prototype is to fly at 240 m/s at 10-km standard altitude. The viscosity is changing with temperature as $\frac{\mu}{\mu_o} = (\frac{T}{T_o})^{0.7}$ .What should the tunnel pressure be in **atm** to scale both the Mach number $(\frac{Velocity}{sound\ speed})$ and the Reynolds number accurately? ***Use table 1.*** Use **(T_o= 288 K, μ_o = 1.8 × 10^{-5} Pa.s)**

b. Derive the dimensionless numbers affecting the flow from the following X – momentum equation:

$$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=-\frac{\partial P}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)$$

Explain the essential meaning of the obtained dimensionless groups.

Question 2 (3+5+13=21) Marks ILOs no.: b2, b3, c1, c18& d7

a. The X- component of the shear force acting on a fixed volume element is given by:

$$F_{fx}=\frac{\partial}{\partial x}\left[\mu\left(2\frac{\partial u}{\partial x}-\frac{2}{3}\nabla\cdot\vec{V}\right)\right]+\frac{\partial}{\partial y}\left[\mu\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)\right]+\frac{\partial}{\partial z}\left[\mu\left(\frac{\partial w}{\partial x}+\frac{\partial u}{\partial z}\right)\right]$$

Simplify the expression for an incompressible fluid flow with constant viscosity.

b. Two velocity components of a steady, incompressible, three-dimensional flow field are known, namely, **u** = **$ax^2 + by^2 + cz^2$** and **w** = **axz + byz^2**, where **a, b,** and **c** are constants. The **y** velocity component is missing. Generate an expression for **v** as a function of **x, y,** and **z** knowing that **v = 0 at y = 0.**

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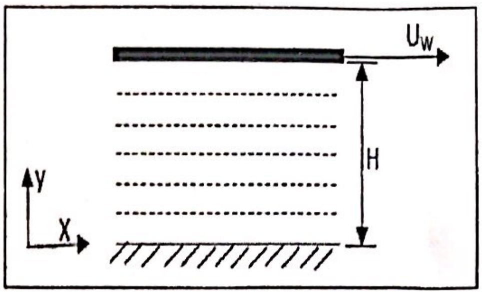
c. Newtonian liquid (density ρ, viscosity μ) flows steadily between two horizontal plates. The upper plate moves with a velocity Uw while the lower is fixed. The pressure decreases in the **X**-direction linearly, constant negative pressure gradient. For given values of **H**, ρ, μ, Uw, and $\frac{dp}{dx}$, obtain:

- i- The relation of **u(y)**.
- ii- The ratio of shear stresses at **(y = H)** and **(y = 0)**.
- iii- The volume flow rate for a plate depth **B**.
- iv- The maximum velocity for **Uw = 0**.
- v- The momentum flux for **Uw = 0**.
- vi- Sketch the velocity and shear stress distribution for **Uw = 0, Uw < 0** and **Uw > 0**.



Question 3 (2+3+15= 20) Marks ILOs no.: b1, b2, b3, c1, c18& d7

a. **Draw** the growth of **boundary layer** over a flat plate including a reverse pressure gradient showing the velocity distributions in each region.

b. **Mention, with sketch and brief discussion, three ways used to control separation.**

c. The velocity distribution in the boundary layer is given by $\frac{u}{U} = \frac{3}{2}\left(\frac{y}{\delta}\right) - \frac{1}{2}\left(\frac{y}{\delta}\right)^3$. As δ is the boundary layer thickness. Assuming laminar boundary layer:

i- Prove that:

a- $\frac{\delta_1}{\delta} = \frac{3}{8}$

b- $\frac{\delta_2}{\delta} = \frac{39}{280}$

c- $\delta = \frac{4.64\, x}{\sqrt{Re_x}}$

d- $C_D = \frac{1.292}{\sqrt{Re_L}}$

ii- Find the drag force per unit depth of a flat plate, if the free stream velocity is 2 m/s, length of plate is 3 m, dynamic viscosity is 1.8×10^{-5} Pa.s, and density of air is 1.2 kg/m^3.

Question 4 (3+10 = 13) Marks ILOs no.: b2, b3, c1, c18& d7

a. What meant by **Skin Drag, Form Drag and Total Drag.**

b. A spherical deep-probe is drawn up from a depth **H** with constant velocity during a time **T** from the sea ground to a ship. For **(D= 0.5 m, H = 4000 m, T= 3 hrs, ρ = 1000 kg/m³, μ = 0.001 Pa.s and g = 10 m/s²)**, and regarding ***figures (4a and 4b),*** find :

i- The weight of the probe if the tension in the rope is 2700 N.

The time required for lifting the probe if the tension in the rope is doubled.

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Table 1

z, m	T, K	p, Pa	ρ, kg/m³	a, m/s
−500	291.41	107,508	1.2854	342.2
0	288.16	101,350	1.2255	340.3
500	284.91	95,480	1.1677	338.4
1,000	281.66	89,889	1.1120	336.5
1,500	278.41	84,565	1.0583	334.5
2,000	275.16	79,500	1.0067	332.6
2,500	271.91	74,684	0.9570	330.6
3,000	268.66	70,107	0.9092	328.6
3,500	265.41	65,759	0.8633	326.6
4,000	262.16	61,633	0.8191	324.6
4,500	258.91	57,718	0.7768	322.6
5,000	255.66	54,008	0.7361	320.6
5,500	252.41	50,493	0.6970	318.5
6,000	249.16	47,166	0.6596	316.5
6,500	245.91	44,018	0.6237	314.4
7,000	242.66	41,043	0.5893	312.3
7,500	239.41	38,233	0.5564	310.2
8,000	236.16	35,581	0.5250	308.1
8,500	232.91	33,080	0.4949	306.0
9,000	229.66	30,723	0.4661	303.8
9,500	226.41	28,504	0.4387	301.7
10,000	223.16	26,416	0.4125	299.5
10,500	219.91	24,455	0.3875	297.3
11,000	216.66	22,612	0.3637	295.1

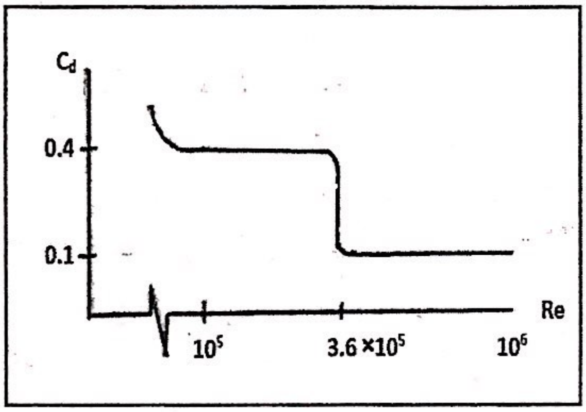

Figure 4a

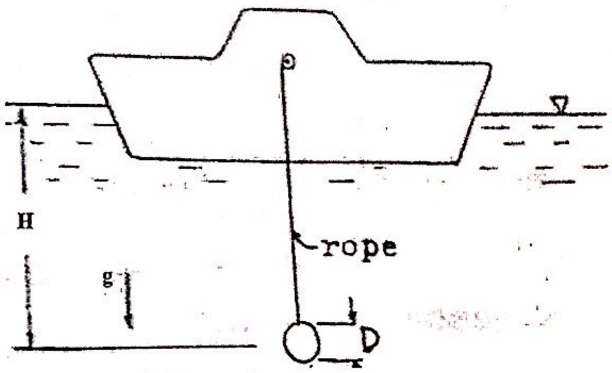

Figure 4b

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