UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: January 2022

Module Number: ME6201 **Module Name: Advanced Fluid Mechanics**

[Three Hours]

[Answer **all questions**; Each question carries **twelve marks**; Provide neat sketches where necessary; Make reasonable assumptions and state them clearly]

Q1 a) Write brief notes on the following.

i) Steady and unsteady flows.

ii) Uniform and non-uniform flows.

iii) Laminar and turbulent flows.

[1.5 Marks]

b) Briefly describe **four** methods of preventing separation of the boundary layer.

[2.0 Marks]

c) Describe the effect of pressure gradient on boundary layer separation considering a flow over a curved surface.

[2.5 Marks]

d) Water is flowing over a thin smooth plate of length 5 m and width 2 m at a velocity of 1.0 m/s. If the boundary layer flow changes from laminar to turbulent at a Reynold number 5×10^5, considering density = $1000\,\text{kgm}^{-3}$, and dynamic viscosity(μ)= $1\times10^{-3}\,\text{Ns/m}^2$ find the followings. (Drag coefficient for a laminar flow $=\frac{1.328}{\sqrt{Re_L}}$ and for a turbulent flow $=\frac{0.072}{\sqrt[5]{Re_L}}$)

i) The distance from leading edge up to which boundary layer is laminar.

[1.0 Mark]

ii) The drag force on one side of the plate due to the laminar boundary layer.

[2.0 Marks]

iii) The drag force on one side of the plate due to turbulent boundary layer.

[3.0 Marks]

Q2 a) What are the **three** types of forces acting on the rigid particle moving through a fluid?

[1.5 Marks]

b) Mention **four** applications of fluidization.

[2.0 Marks]

c) Mention **three** restricted conditions of using drag coefficient vs Reynold's number graph of a particle.

[1.5 Marks]

d) Explain **free settling** and **hindered settling** of particle motion.

[2.0 Marks]

e) Spherical particles of density 2500 kg/m^3 and in the size range 20 - 100 μm are fed continuously into a stream of water (density, 1000 $kg/m^3$and viscosity, 0.001 Pas) flowing upwards in a vertical, large diameter pipe. What maximum water velocity is required to ensure that no particles of diameter greater than 60 μm are carried upwards with the water?

[5.0 Marks]

Q3 a) Write brief notes on the following.

i) Deformed layer.

ii) Chemically reacted layer.

iii) Physisorbed layer.

iv) Chemisorbed layer.

[2.0 Marks]

b) Briefly describe the influence of temperature rise during frictional heating on the behaviour of a tribological system.

[2.0 Marks]

c) Derive an equation to find the load to initiate yield considering Von Misses stress criterion under simple shear in case of axisymmetric contact of two spheres.

[2.0 Marks]

d) A hardened steel sphere of 8 mm radius lies on a thick flat plate of the same material and is loaded against it. The uniaxial yield strength of both materials is 1.5 GPa. Take, Young's modules E = 210 GPa and Poisson's ratio $v = 0.3$.

Q3 is continued to page 3

i) Calculate the applied load (W_y) and the mean contact pressure (p_m) at the onset of subsurface yield in the plate considering Von misses stress criterion under simple shear.

[3.0 Marks]

ii) Calculate the depth below the surface at which yield initiates.

[1.0 Mark]

iii) To avoid the possibility of yield, a decision is made to reduce the load so that the maximum pressure is only half of the yield stress. Calculate the maximum load that can now be carried.

[2.0 Marks]

Q4 a) Mention **four** characteristics of good lubricants.

[2.0 Marks]

b) Mention **two** major factors which affect the selection of lubricants?

[2.0 Marks]

c) Is it advisable to use the recommended lubricant of a diesel engine for lubricating gasoline engine? Explain the reasons.

[2.0 Marks]

d) Explain an advantage of using hydrostatic lubrication compared to the hydrodynamic lubrication using a neat and clear sketch of a bearing system.

[2.0 Marks]

e) A circular hydrostatic pad, as shown in Figure Q4 (e), is supporting a load of W = 1000 N, and the upper disk has a rotational speed of 5000 rpm. The disk diameter is 200 mm, and the diameter of the circular recess is 100 mm. The oil is SAE 10 at an operating temperature of 70 °C, having a viscosity of μ=0.01 Ns/m^2. The efficiency of the hydraulic pump system is 0.6 and that of the motor and drive system is 0.9. Calculate the pressure in the recess.

Q4 is continued to page 4

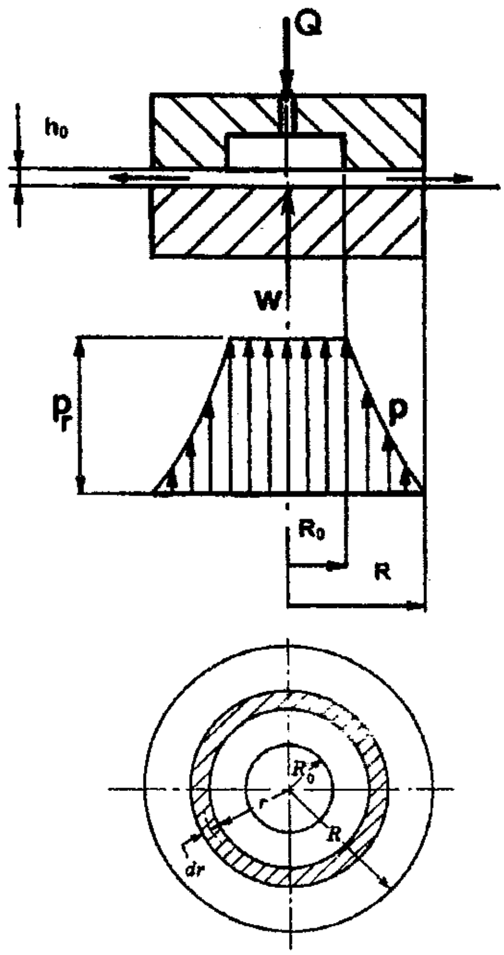


Figure Q4 (e)

[4.0 Marks]

Q5 a) Mention **two** industrial applications of two-phase flows.

[2.0 Marks]

b) Discuss the reasons for calculations complexities associated with two-phase flows compared to the single flow.

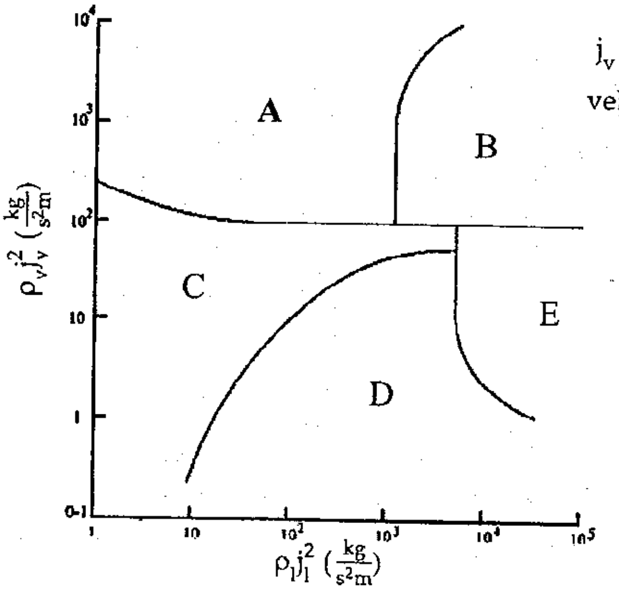
[2.0 Marks]

c) Mention **two** assumptions that are used to simplify the pressure drop of two-phase flows.

[2.0 Marks]

Q5 is continued to page 5

d) Figure Q5 (d) represents the flow-pattern map of a vertical upward gas-liquid co-current flow. Identify the A, B, C, D, and E regions mentioned on the map.



j_v and j_l are the superficial velocities of vapour and liquid

Figure Q5 (d)

[2.0 Marks]

e) Refrigerant R134a flows through a vertical 10 mm diameter tube and it has a vertical upward flow of 0.08 kg/s. The tube is at -20 °C and mass quality is 25%. Liquid and vapour densities of the R134a at -20 °C are 1358 kg/m^3 and 6.785 kg/m^3 respectively.

i) Find the mass flux of the refrigerant R134a.

[1.0 Mark]

ii) Calculate superficial velocities of liquid and vapor phases.

[2.0 Marks]

iii) Identify the flow regime by considering Figure Q5 (d).

[1.0 Mark]

Useful equations with usual notations.

$$V_T = \frac{D_p^2 \left(\rho_p - \rho_f\right) g}{18\mu}$$

$$F_D = 3\pi\mu U D_P$$

$$\Delta P = \frac{150\ \mu L U_\infty (1-\varepsilon)^2}{D_p^2 \varepsilon^3} + \frac{1.75\rho L U_\infty^{\ 2}(1-\varepsilon)}{D_p \varepsilon^3}$$

$$P = \frac{6\eta Q}{\pi h^3 \cos\phi} \ln\left(\frac{R}{r}\right)$$

$$W = \frac{P_r \pi}{2\cos\phi}\left[\frac{R^2 - R_0^2}{\ln(R/R_0)}\right]$$

$$H_f = 2\pi^3 \eta n^2 \left[\frac{R_0^4}{h_r} + \frac{(R^4 - R_0^4)}{h \cos\phi}\right]$$

From Hertz analysis	the contact radius	$a = \frac{\pi p_0 R}{2E^*}$
	The load supported by the contact	$W = \int_0^a 2\pi r p(r) dr = \frac{2}{3} p_0 \pi a^2$
In the case of axisymmetric contact of two spheres		
- By the Tresca criterion, the value of p_0 for yield		$(p_0)_y = 3.2k = 1.60Y$
- By the Von mises criterion, the value of p_0 for yield		$(p_0)_y = 2.8k = 1.40Y$