UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: November 2022

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

[Three Hours]

[Answer **all questions**, each question carries **12** marks]

Useful equations with usual notations are given in page number 06

Q1 a) Briefly describe **four** methods of reducing the effect of drag on solid bodies.

[2.0 Marks]

b) Briefly describe the effect of skin friction drag and pressure drag on the following when,

i) A flat plate is placed parallel to a flow

ii) A flat plate is placed perpendicular to a flow

[2.0 Marks]

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

[3.0 Marks]

d) A submarine length 50 m and diameter 5 m can be assumed to have cylindrical shape with rounded nose cruises at a velocity of 8 m/s in sea water. If the boundary layer flow changes from laminar to turbulent at a Reynolds Number 5×10^5, considering density of sea water = $1030\, kgm^{-3}$ at 20 °C, and kinematic viscosity(v) = $1 \times 10^{-6}\, m^2/s$ find the followings,

Note: State any assumptions made

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

[2.0 Marks]

ii) The total drag force.

[2.0 Marks]

iii) The power required to overcome the boundary friction.

[1.0 Marks]

Q2 a) Mention **one** application of fluidization and explain the process.

[3.0 Marks]

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

[2.0 Marks]

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

[2.0 Marks]

d) A cricket ball is thrown with a Reynolds Number such that the drag coefficient is 0.4 ($Re \approx 10^5$). (In both cases take the mass and diameter of the ball as 0.15 kg and 6.7 cm respectively and the density of air as 1.2 kg/m^3.)

i) Find the percentage change in velocity of the ball after 100 m horizontal flight in air.

[2.0 Marks]

ii) With a higher Reynolds Number and a new ball, the drag coefficient falls to 0.1. What is the percentage change in velocity over 100 m horizontal flight?

[3.0 Marks]

Q3 a) Write brief notes on following applications of tribology.

i) Automotive Tribology.

ii) Tribology in Manufacturing.

iii) Bio Tribology.

[3.0 Marks]

b) Write down **three** differences between **chemisorption** and **physisorption**.

[1.5 Marks]

c) Derive an equation to find the load to initiate yield considering Von Mises 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 and considering Young's modulus, E = 210 GPa and v = 0.3,

Q3 is continued to page 3

i) Calculate the applied load (Wy) and the mean contact pressure (pm) 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 Marks]

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.

[1.5 Marks]

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

[2.0 Marks]

b) State **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=1000N, 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.

[4.0 Marks]

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

[2.0 Marks]

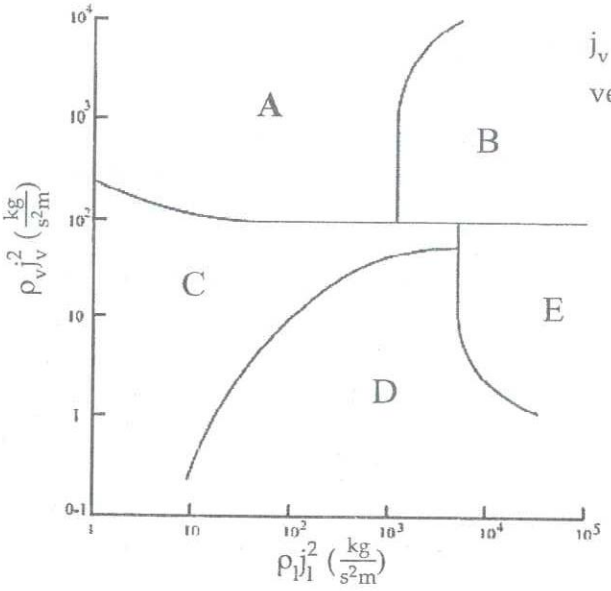
b) Discuss the reasons for calculations complexities associated with two-phase flows compared to the single flow.

[2.0 Marks]

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

[2.0 Marks]

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) Derive a relation to express the mass quality (x) in terms of volumetric quality (β) and the density ρ_G and ρ_L of the phases.

[4.0 Marks]

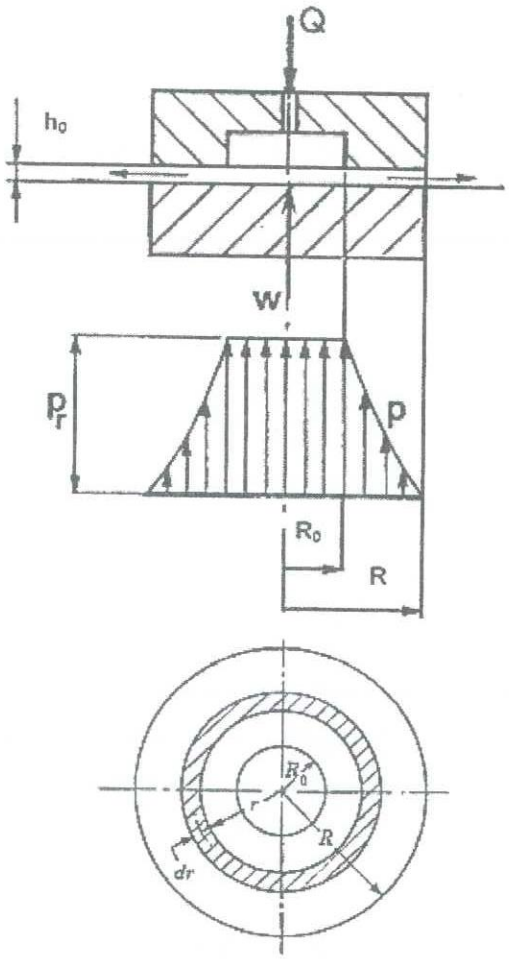


Figure Q4 (e)

Useful equations with usual notations

$V_T=\frac{D_p^2(\rho_p-\rho_f)g}{18\mu}$	$P=\frac{6\eta Q}{\pi h^3 \cos\phi}\ln\left(\frac{R}{r}\right)$
$F_D=3\pi\mu UD_P$	$W=\frac{P_r\pi}{2\cos\phi}\left[\frac{R^2-R_0^2}{\ln(R/R_0)}\right]$
$\Delta P=\frac{150\,\mu LU_\infty(1-\varepsilon)^2}{D_p^2\varepsilon^3}+\frac{1.75\rho LU_\infty{}^2(1-\varepsilon)}{D_p\varepsilon^3}$	$H_f=2\pi^3\eta n^2\left[\frac{R_0^4}{h_r}+\frac{(R^4-R_0^4}{h\cos\phi}\right]$

Drag Coefficient for laminar flow	$=\frac{1.328}{\sqrt{Re_L}}$
Drag Coefficient for turbulent flow	$=\frac{0.072}{\sqrt[5]{Re_L}}$ (for $5 \times 10^5 < Re_L < 10^7$)
	$=\frac{0.455}{(log_{10}Re_L)^{2.58}}$ (for $10^7 < Re_L < 10^9$)
Drag Coefficient for combined flow	$=\frac{0.455}{(log_{10}Re_L)^{2.58}}-\frac{1700}{Re_L}$ (for $10^7 < Re_L < 10^9$)

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		$(p_0)_y=2.8k=1.40Y$