Time = 60 minutes

Maximum marks = 100

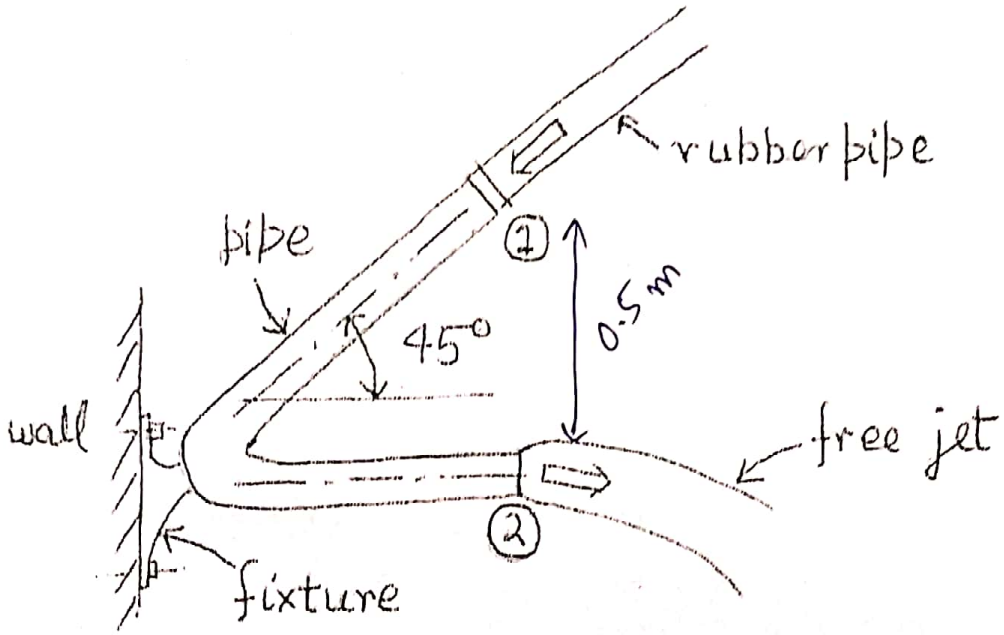
Major Exam

APL 105 (Fluid Mechanics Part); Spring 2019

Closed Book, Closed Notes

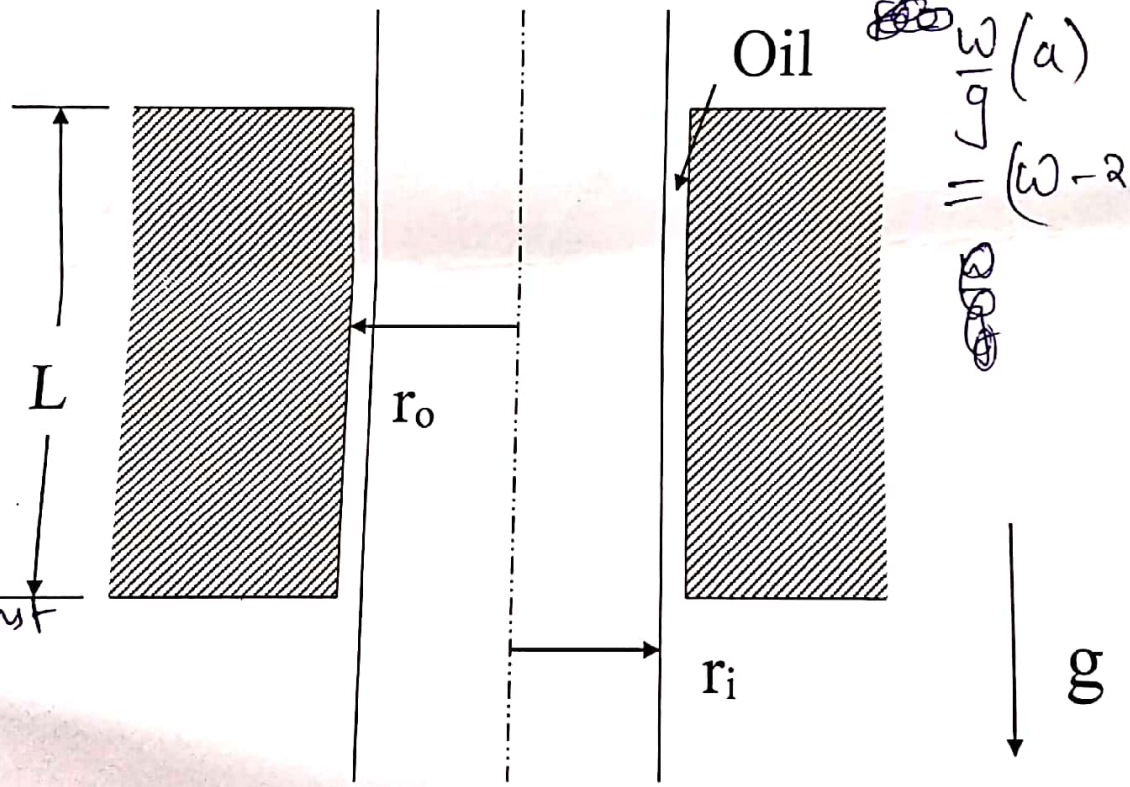
Note: You will be graded not only for your answers, but also for your steps and diagrams. Just writing the final answer will not fetch you any marks. Neatness and order will also fetch more marks. Do not write anything on the question sheet—show all the work in the given answer sheet.

1. Water is flowing through a bent pipe shown below at the rate of 1 kg/s. If the inner pipe diameter is 3 cm and no force is being transmitted through the rubber pipe, do the following parts: (a) If the head loss due to friction inside the pipe is 10 m, find the gage pressure at the inlet 1. (b) Estimate the horizontal and vertical components of force provided by the fixture to keep the pipe fixed in its place. (Sketch the support force vector.) Take the density of water to be 10^3 kg/m^3 and the acceleration due to gravity to be 10 m/s^2. Take the elevation of point 1 with respect to point 2 to be 0.5 m. Make other necessary assumptions. (40 marks)



2. A vertical cylinder with an outer radius r_i is placed concentrically in a circular hole of radius r_o and length L. As shown below, the small gap between the cylinder and hole is filled with a viscous oil of density ρ and viscosity μ. (a) Derive the expression for velocity in the gap region under steady-state conditions when the cylinder is falling down with a steady velocity V. (b) If weight of the cylinder is W, then derive an expression for the velocity V in terms of the given variables.

Helpful comments: Take the pressure at the entrance and exit of the annular gap to be atmospheric. Note that apart from gravity and forces from the fluid in the hole, no other force is acting on the cylinder which is moving down with a steady velocity. Do include the effect of gravity in your fluid-flow solution. (40 marks)



3:

(a) When Re → 0, the N-S equations reduce to …. (1 marks)

(b) When Re → infinity, the N-S equations reduce to …. (1 marks)

(c) Explain with a figure what is von-Karman vortex street? (2 marks)

(d) Which of the following pi groups decides the frequency of vortex shedding: Fr, Ma, St, C_D. (1 marks)

(e) Is C_D a function of Re – true or false? (1 marks)

(f) Give the formula for finding the force per unit area acting on a surface from the stress tensor, σ, and the unit normal, n. (1 marks)

(g) Give the formula for pressure jump across an air-liquid interface in terms of surface tension and radii of curvatures. (2 marks)

(h) Give the constitutive relation between the shear stress and the strain-rate tensor. (2 marks)

(i) The diagonal components of the strain-rate tensor give (choose one): linear strain rate, shear strain rate (1 marks)

(j) Give the name of the shape of the velocity profile seen in a pipe during laminar flow under fully-developed conditions. (1 marks)

(k) Derive the formula for pressure increase with depth under hydrostatic conditions from the Navier-Stokes equations. (3 marks)

(l) The volume flow Q through an orifice plate is a function of pipe diameter D, pressure drop Δp across the orifice, fluid density ρ and viscosity μ, and orifice diameter d. Find how many π groups will be there in this problem. (4 marks)