National Exams December 2008

07-Mec-B6, Advanced Fluid Mechanics

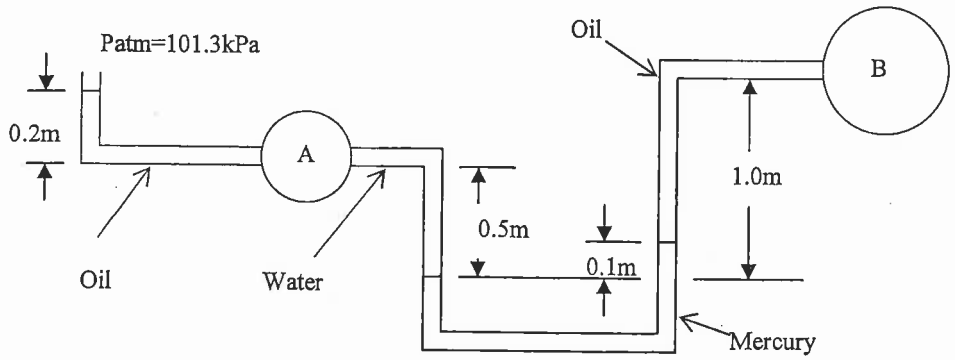
3 hours duration

Notes:

1. If doubt exists as to the interpretation of any question the candidate is urged to submit with the answer paper a clear statement of the assumptions made.
2. Candidates may use any non-communicating calculator. The exam is OPEN BOOK.
3. Answer all 3 of the 3 questions in **part A** and any 3 of the 4 question of **part B**. If more questions are attempted, these will be marked in the order presented.
4. Weighting: Part A: 40%; Part B: 60% . Within each section, the questions have equal weighting.

PART A: Answer all **3** of the 3 questions in this section.

Question A.1: Using the manometer rule, determine the pressure in pipe "B" given the following arrangement. An open tube manometer contains an oil of density ρ=800kg/m^3. It is connected to a pipe "A" containing water (ρ=1000kg/m^3). This pipe is connected to pipe "B" through a U-tube manometer which is filled with water in the left leg, with mercury at the bottom (ρ=13600kg/m^3) and then oil (ρ=800kg/m^3) up to pipe "B". Express your answer in both absolute and gauge pressures.



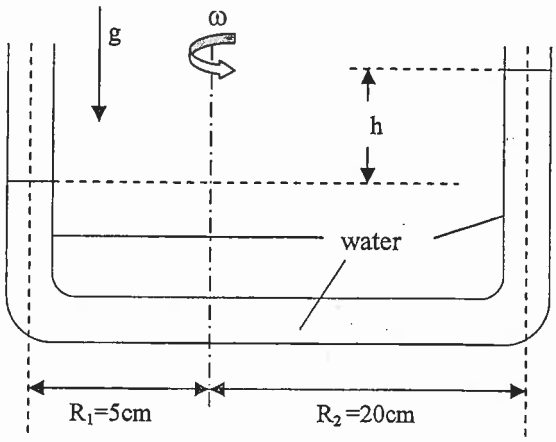
QUESTION A.2: A spillway consists essentially of a rectangular channel 100m wide. The flow rate of water is to be 3548 m^3/s at an average speed of 10m/s. You are to investigate the resulting hydraulic jump in the laboratory by using a scaled model. The model you have is a rectangular channel 1m wide and your pump can only generate an average speed of 1m/s of water.

a) What must be the Froude number of the flow upstream of the hydraulic jump?
b) What flow rate must you maintain in the laboratory set-up?
c) What is the flow level after the hydraulic jump in your laboratory and in the spillway?
d) What is the Froude number downstream of the jump in the laboratory and the spillway? Is it the same? Why?

Question A.3: A U-tube manometer filled with water is made to rotate at a rate of 120 rpm about an axis as shown in the adjacent figure. What will be the recorded height difference h? The ends of the manometer are open to atmosphere.

For water use $\rho = 1000$ kg/m^3.

Also, use $g = 9.81$ m/s^2.



Section B Answer any **3** of the 4 questions in this section.

Question B.1: The streamfunction corresponding to the superposition of a clockwise rotating potential vortex placed at $y=a$ and a counter-clockwise rotating potential vortex at $y=-a$ is given by:

$$\psi = \frac{K}{2}\left[\ln\left(x^2+(y-a)^2\right)-\ln\left(x^2+(y+a)^2\right)\right] \qquad K>0$$

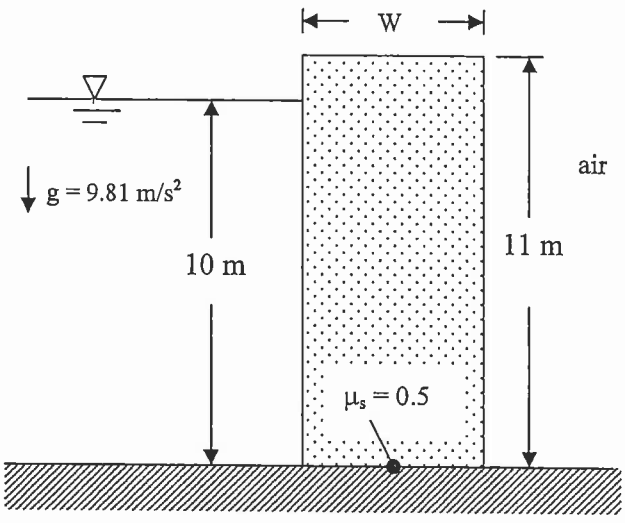
a) Show that the x-axis (y = 0) is a streamline and determine the pressure distribution along the x-axis in terms of the static pressure P and the stagnation pressure Po.
b) Determine the force per unit depth (magnitude and direction) on the vortex at y=a due to the vortex at y=-*a*? What is the force on the vortex at y=-a due to the vortex at y=*a*?

Question B.2: Air flows from a reservoir where the pressure is 300kPa and the temperature is 500K through a throat of a convergent-divergent nozzle. Downstream of the throat, there is a normal shock. The area of the throat is $1m^2$. At the location of the shock, the area is $2\ m^2$.

a) Determine the Mach number, static pressure and flow speed directly upstream of the shock. What is the mass flow rate?
b) Determine the Mach number, the mass flow rate, the stagnation temperature and pressure, the static pressure and the flow speed directly downstream of the shock.

Question B.3:

A dam is built to retain sea water (ρ = 1030 kg/m^3). It consists of a rectangular concrete slab (ρ = 2500 kg/m^3) of height 11m resting on a non-porous bed as shown in the adjacent figure. The maximum water dept is 10m. If the coefficient of dry friction between the soil and the concrete is given as $\mu_s = 0.5$, determine the necessary width, W, of the dam to ensure that it will retain the water without tipping over or slipping. You may assume that the dam is uniform in the span.



Question B.4: Given a pipe section, shown in the figure below, that protrudes from the wall, calculate the forces, torsional (M_y) and bending (M_x) moments applied by water flowing inside the pipe at a rate of 300 kg/s, on the base-plate of the pipe. The pipe diameter is a constant 20 cm and the bends are both 90°. The loss coefficient in the elbows is 0.28. You may neglect frictional losses.