ES2A7 - Fluid Mechanics Example Classes

Example Questions (Set II)

<u>Question 1:</u> DIMENSIONAL ANALYSIS

Use dimensional analysis to determine the period t for small oscillations of a simple pendulum (Fig. 1) of length l. Assume that the period depends on the length of the pendulum, the mass of the oscillating body and the gravitational acceleration of the Earth. (N.B.: You will find that the correct answer to the question will imply that the period must in fact be independent of the mass of the oscillating body.)

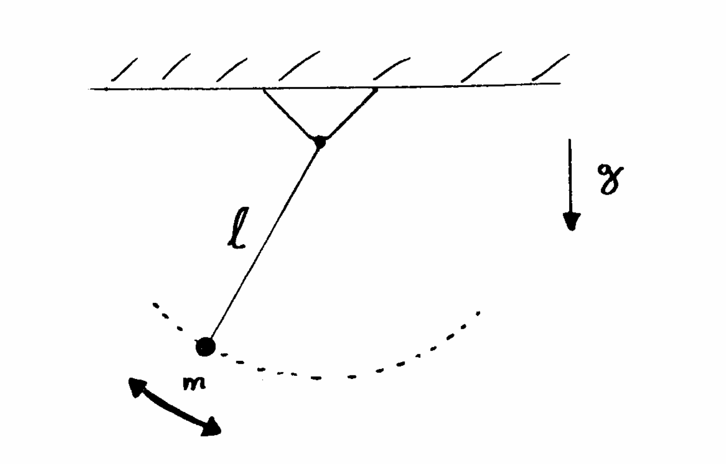

Figure 1: Sketch of Pendulum Geometry

<u>Question 2:</u> Dynamic Similarity

The flow around an airship with a diameter $d = 3\,\text{m}$ and a length $l = 20\,\text{m}$ needs to be studied in a wind tunnel. The airspeed range to be investigated is at the docking end of its range, a maximum of $v_p = 2\,\text{ms}^{-1}$. Calculate the mean model wind tunnel speed if the model is made to 1/10 scale. Assume the same air pressure and temperature for model and prototype.

<u>Question 3:</u> Manometer

In Fig. 2 the liquids at A and B are water and the manometer liquid is oil. Given are the density of water $\rho_w = 1000$ kgm^{-1}, the density of the oil $\rho_o = 800$ kgm^{-1}, $h_1 = 300$ mm, $h_2 = 200$ mm, $h_3 = 600$ mm, the gravitational acceleration of the Earth $g = 9.81$ ms^{-2}. Determine the pressure difference $p_A - p_B$ in Pascals.

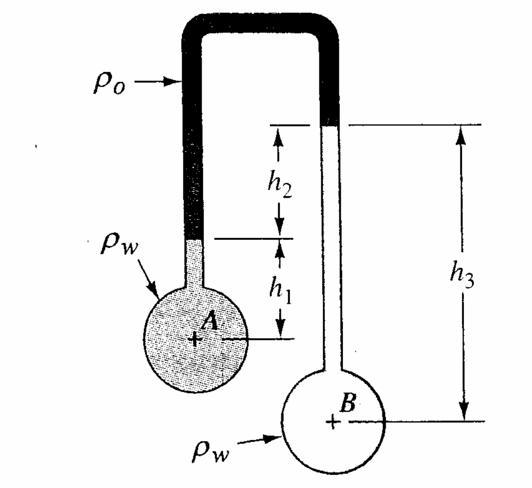

Figure 2: Differential Manometer

<u>Question 4:</u> Sliding Board

A board with an area $A = 1\,m \times 1\,m$ slides down an inclined ramp as is schematically illustrated in Figure 3. The ramp is inclined at an angle $\alpha = 14^\circ$. The weight of the board is W=40N and it slides with a constant velocity of U=3.0 cm s^{-1}. The board is separated from the ramp by a thin film of oil with a dynamic viscosity of $\mu = 0.05$ N s m^{-2}. Assume that edge effects are negligible. Assume further that the distribution of the fluid velocity across the oil-filled gap between the ramp and the board is linear. Calculate the gap width d between the board and the ramp. (Hint: The board slides at a constant velocity when the component of the weight parallel to the inclined ramp is equal to the resisting shear force.)

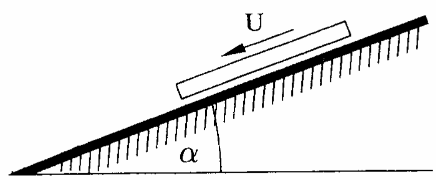

Figure 3: Board Sliding on Ramp

<u>Question 5:</u> Discharge from Nozzle of a Reservoir

Use the Bernoulli equation and mass conservation to find a relation between the nozzle discharge velocity V^2 and tank free-surface height h as shown in Figure 4.

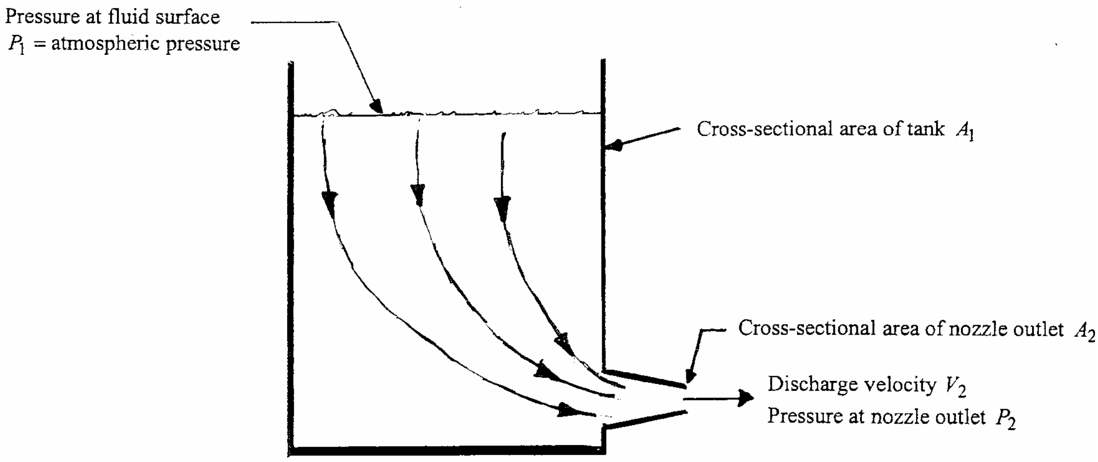

Figure 4: Discharge from Nozzle of a Reservoir

<u>Question 6:</u> Transition of Pipe Flow

A Reynolds number for flow in a circular pipe is defined as $\mathrm{Re} = \mathrm{V}d/\nu$ (V: flow velocity averaged across the cross section of the pipe d: pipe diameter, ν: kinematic viscosity of the fluid flowing inside the pipe. The accepted critical Reynolds number for laminar-turbulent transition for the flow is Re ≈2300. For flow through a 60 mm-diameter pipe, at what velocity will this occur for (a) water with $\nu = 10^{-6}$ $m^2.s^{-1}$ and (b) air with a dynamic viscosity of $\mu = 1.82 \times 10^{-5}$ kg m^{-1} s^{-1} and a density ρ=1.205 kg m^{-3}.

<u>Question 7:</u> Minimum Flight Speed of Plane

Calculate the minimum flight speed U of an aircraft flying at constant altitude. Consider an aircraft with maximum take-off mass m= 30,740 kg, a lift coefficient C_L=1.2 and a total lifting surface of A=140 m^2. Assume that the cruising altitude is 10 km where the density of air is ρ=0.0414 kg.m^{-3} and the acceleration due to gravity is g=9.776 m.s^{-2}. (Hint: For horizontal flight the lift force must balance the gravitational force)

<u>Question 8:</u> Sprinter

Consider a sprinter running with velocity V_0=10 m.s^{-1} in still air (density: ρ=1.2 kg.m^{-3}) as shown in Figure 5. Luckily the sprinter measured the atmospheric pressure before he set off and phoned you up to tell you that it is equal to P_A=101.3 kPa. What pressure will the sprinter experience while running?

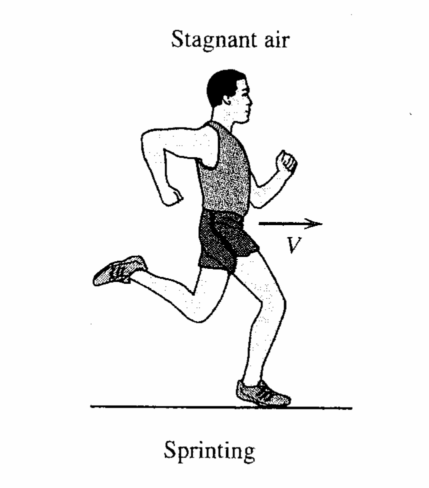

Figure 5: Sprinter