MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
2.06 Fluid Dynamics

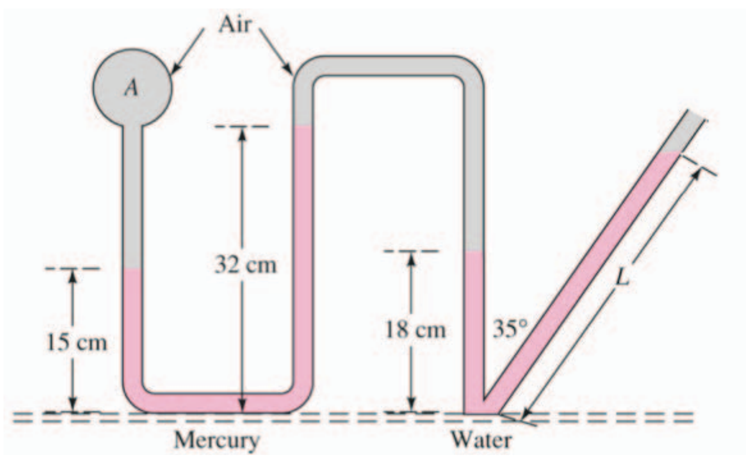
PROBLEM SET #1, Spring Term 2013
Issued: Thursday, April 4, 2013 **Due: Thursday, April 11, 2013, 1:05 PM**

Objective: The goals of this Problem Set are to (i) learn about fluid statics, pressure forces, and buoyancy forces (ii) apply these concepts to simple fluidic engineering systems.

Problem 0: Please read chapter 2 in White.

Problem 1: Shorter Concept Questions

i. Hydrostatics



The system above is open to atmospheric pressure (10^5 Pa) on its right side.

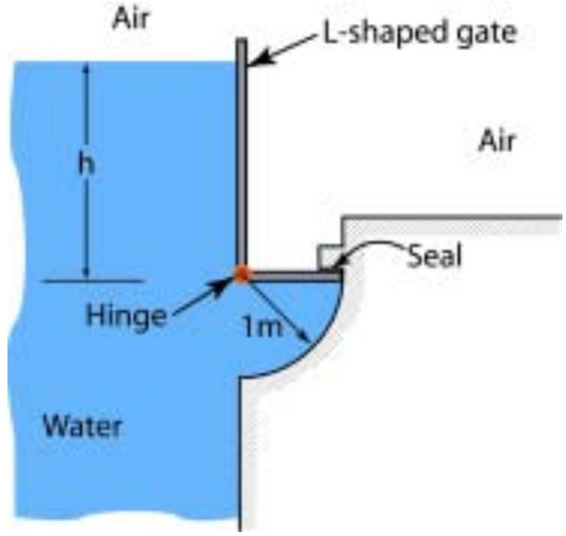
a) If L=120 cm, what is the air pressure in container A?

b) Conversely, if p_A = 135 kPa, what is the length L? Assume the density of water and mercury are 1,000 kg/m^3 and 13,560 kg/m^3, respectively.

ii. Some of you may have noticed that dams are much thicker at their bottom (e.g. see prob. 2). For example, in the Hoover dam example we considered in the class the thickness of the dam at the top is about 45 feet while the thickness at the bottom is about 660 feet. Can you explain why dams are built that way?

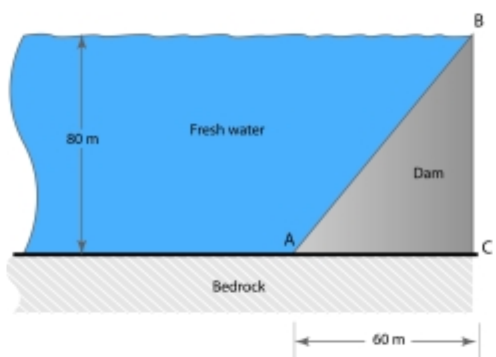
iii. A 10-kg hollow copper ball, a 10-kg solid copper ball and a 10-kg solid copper cube are submerged in a liquid. Will the buoyancy forces acting on these three bodies be the same or different? Explain and justify your answer quantitatively.

Problem 2



An L- shaped gate can rotate about a hinge pin located at its vertex as shown in the figure above. As the water rises, the depth of the hinge pin, h, will reach a critical height h_c and the gate will open. If the length of the lower horizontal arm is 1 m, please find the critical height h_c. (Please neglect the weight of the gate.)

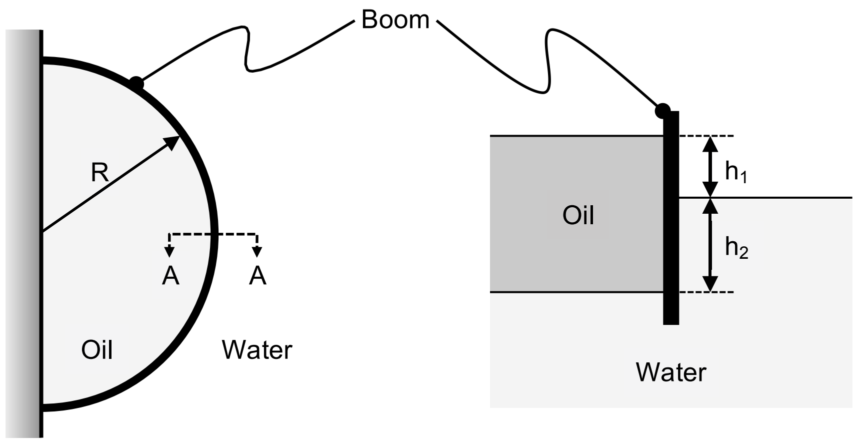
Problem 3



A concrete dam ($\rho_{concrete}$=2500 kg/m^3) of triangular cross-section spans 100 m into the page (i.e., the wetted-area of the dam is 100 m (the length of AB) × 100 m (the width into the page)) in a reservoir as shown above.

a) Please calculate the total force on the dam due to the water and its direction
b) Can this force tip the dam over? Please assume that the dry concrete-bedrock joint is capable of sustaining only negligible tensile stresses and very large compressional stresses. (*Hint: What is the sign and magnitude of the moment about point C?*)
c) Suppose there is seepage of water between the concrete and the bedrock (along line AC). To what percentage of the length of line AC can water uniformly seep without the dam tipping?

Problem 4



Top View **Side View (Section A-A)**

Consider a semi-circular boom of radius R that is deployed to contain oil spill near a dock as shown above. The boom floats on the water and acts as barrier for the spreading oil. The oil has a density ρ_o and water has density ρ_w ($\rho_o < \rho_w$). If a volume V of the oil is spilled, calculate:

a) The elevation h_1 of the top surface and the depth h_2 of the bottom surface of the contained oil relative to the water surface outside the boom

b) The forces exerted by the boom on the dock

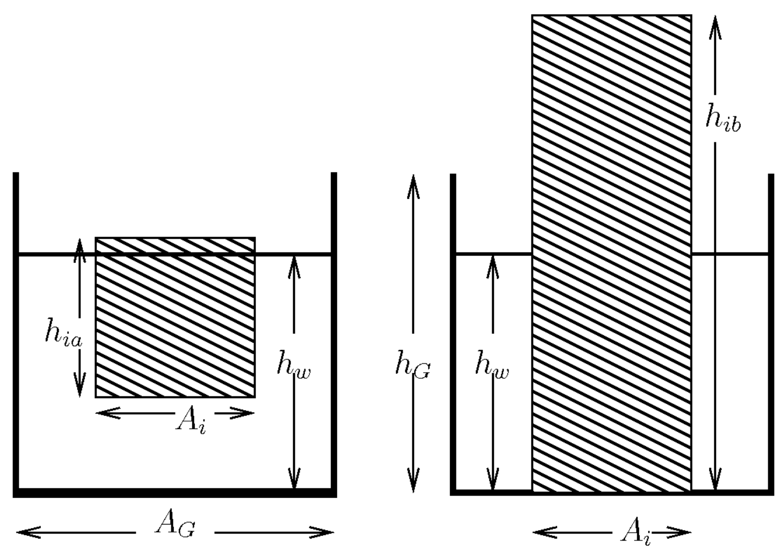
Problem 5

Consider two glasses of water with cross-sectional area $A_G = 10$ cm^2 and a height of $h_G = 20$ cm (see figure). In one of them we place an ice cube of cross-sectional area $A_i = 2.5$ cm^2 and height h_{ia}=10 cm. In the other we place an ice block of cross-sectional area $A_i = 2.5$cm^2 and height h_{ib} = 40 cm. In both glasses the initial height of water is h_w = 15cm. The density of water is ρ_w = 1000kg/m^3 and that of ice ρ_i = 916.6kg/m^3.

a) Determine if block "a" floats and block "b" rests at the bottom (Hint: calculate the different forces acting on the ice in the vertical direction in each case).

b) We now let the ice melt. Calculate the water height in both cases after the ice melts.

c) What is the implication for potential melting of the ice in the Arctic vs. the Antarctic?



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