Mech. 411 --- Quiz 1

March 23, 2006

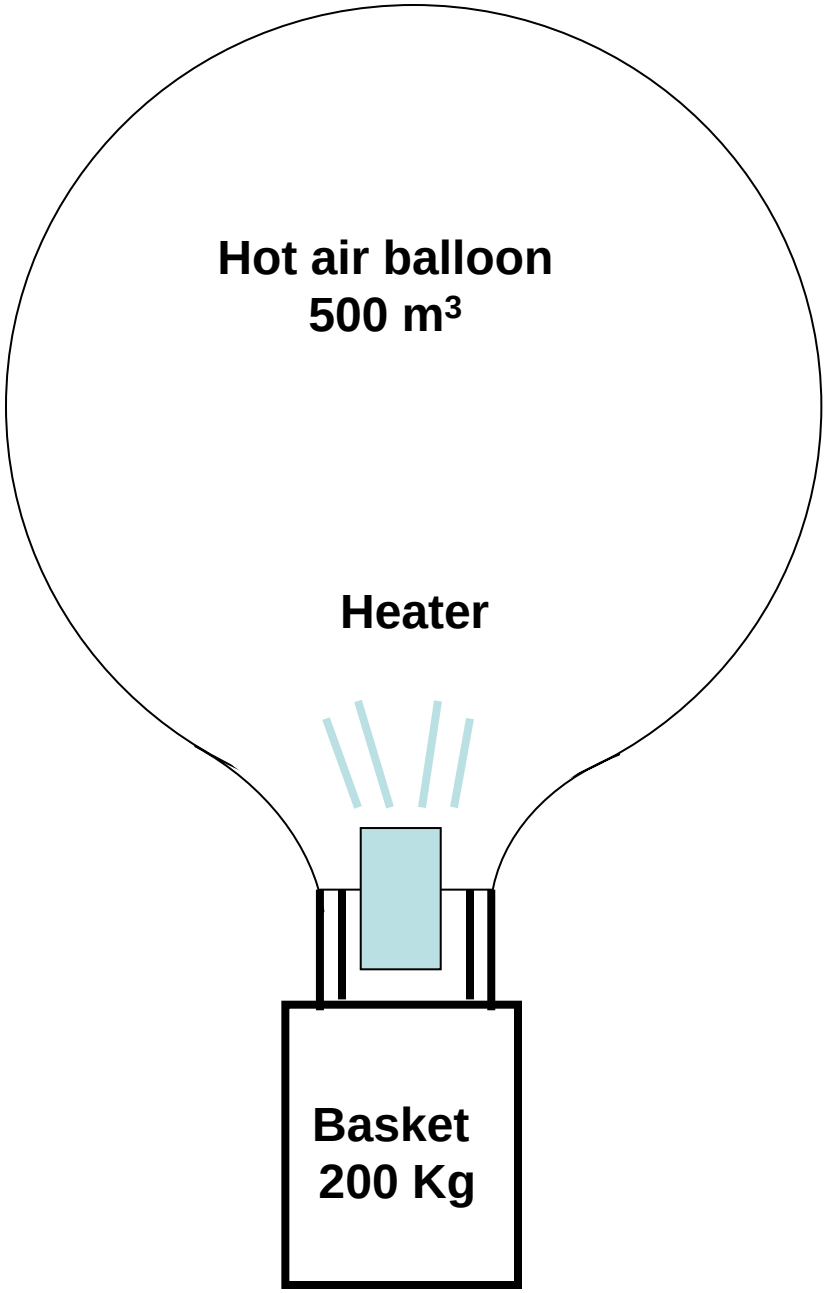
1. [25%] A hot air balloon maintains an average elevation in the quiescent sky at approximately (100 meters) above the ground where the barometer reads (95 KPa). The average sky temperature is (15°C). The balloon is made of a very light non-extendable material, and, when inflated, it is (500 m^3) in size. A small hole at the bottom side of the balloon is designed to fit a heater to control the interior air temperature. The heater weighs 300 N. The hole is open to the atmosphere and thus the pressure inside and outside the balloon is nearly equal. The air properties inside the balloon are uniform. What should the temperature inside the balloon be if it is to lift a basket that is (200 Kg)?

2. [25%] Oil spills may occur in seaports where oil tankers are loaded. The density of oil (ρ_{oil}) is less than the water density (ρ_w) and water and oil do not mix together (immiscible). When oil spills happen, oil spreads out into a uniform layer on top of the water. To prevent the oil spill from spreading any further into the sea, a semi-circular "oil boom" is deployed at a radius (R) around the dock where the tanker is being loaded with oil. Briefly, a boom is a barrier that floats on the water, its bottom submerged and its top slightly above the water surface as shown. Suppose a volume (~~V~~) of oil is spilled inside the boom. After sufficient time has elapsed for the situation to reach static conditions, find in terms of the problem parameters listed above:
    a. The depth h1 of the bottom surface and the elevation h2 of the top surface of the contained oil relative to the water surface outside the boom.
    b. The components of force parallel [Rx] to and transverse [Ry] to the dock exerted by one of the two anchor points at the dock.

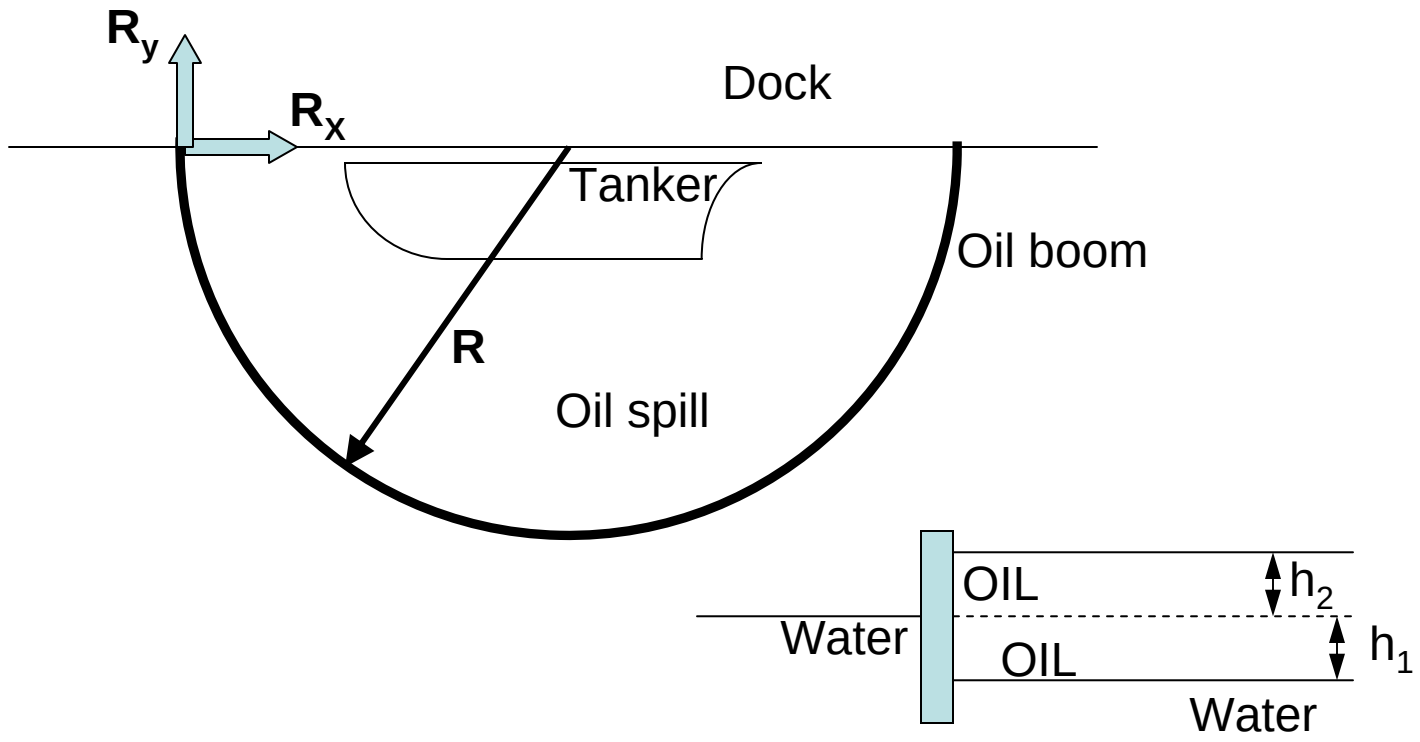
3. [25%] A 10-cm fire hose has a 3 cm nozzle connected to it through a bolted flange as in the figure. Four bolts hold the two parts of the flange together. The water discharges from the nozzle to the atmosphere at a rate of 1.5 m^3/min. Assuming frictionless flow, find the force per bolt (F_B) exerted by the each of the flange bolts to hold the nozzle on the hose.

4. [25%] A rainstorm hits a flat horizontal roof. The rain pours down at a mass flow rate ($\dot{m}$) per unit horizontal area, each drop moving with a constant speed V at an angle (θ) relative to the vertical as shown. When conditions achieve steady state, the water is driven to the right over the roof in a thin layer and over the edge at right. The rain drops splatter onto the top part of the water layer.
    a. Assuming a thin water layer and neglecting gravity find an expression for the pressure at the wall. Assume the slope of the water surface is negligible.
    b. Find an expression for the thickness h(x) of the water layer at x. Assume h=0 at x=0. Neglect any friction forces, and assume h<<x.
    c. For this part assume there is friction at the wall. Would you expect the thickness h(x) to be larger or smaller than the thickness found in part (b)? Why?

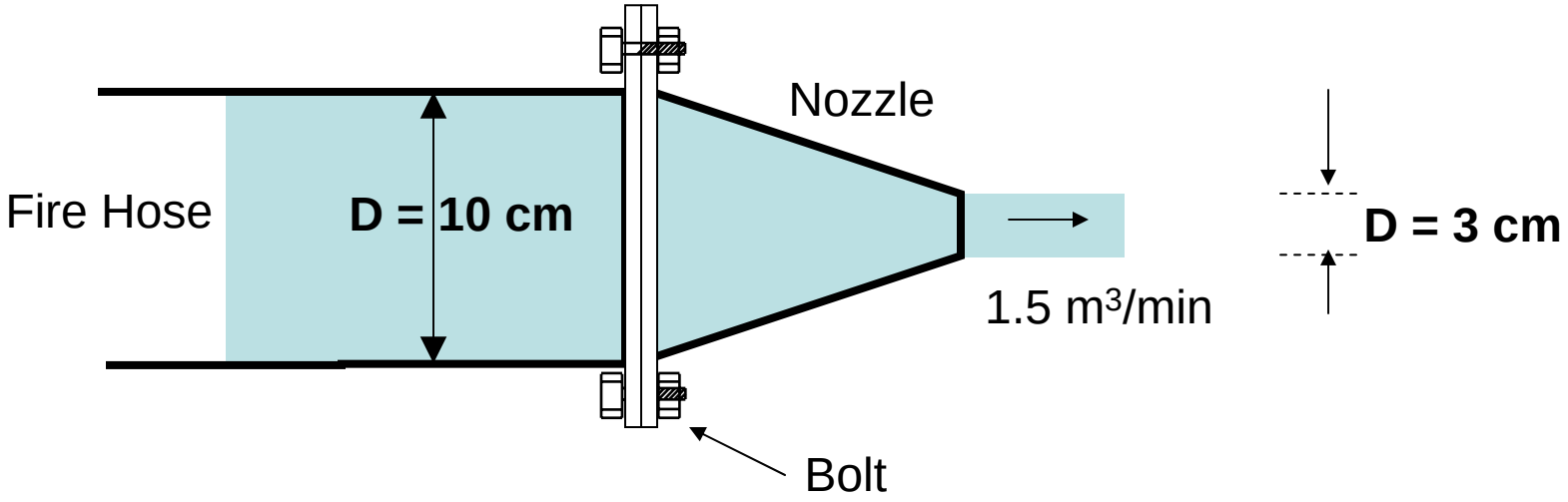
Problem 1



Problem 2


R_y
R_x
Dock
Tanker
Oil boom
R
Oil spill
OIL
h_2
Water
OIL
h_1
Water

Problem 3



Problem 4